SCHOOL OF CIVIL ENGINEERING

INDIANA DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH REPORT

JHRP-84-19

SLOPE STABILITY ANALYSIS WITH STABL4

SUMMARY INFORMATIONAL REPORT

C.W. Lovell
S.S. Sharma
J.R. Carpenter

PURDUE UNIVERSITY

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INTRODUCTION TO SLOPE STABILITY ANALYSIS WITH STABL4

To: R.L. Eskew, Chairman
Joint Highway Research Project
Advisory Board

October 10, 1984

File: 6-14-12

From: H.L. Michael, Director
Joint Highway Research Project

The attached report is an Informational one which summarized much of the work done by the authors is developing an implementation package of the STABL materials for the Federal Highway Administration. This work was performed under a FHWA contract with Purdue University by the authors under the direction of Professor C.W. Lovell.

This summary report is submitted for information and use by IDOH personnel and for sale when requests are submitted to us. Under the implementation program plans of FHWA they will provide copies of the report in the format submitted by us to them under the contract to governmental agencies, but will advise all others (consultants, researchers, etc.) to contact Purdue for copies of the STABL4 materials. Materials supplied will be a copy of the attached report and a tape of the STABL4 program at a price which will cover our costs of handling this activity.

Comments and questions relative to the Report should be directed to Professor Lovell at the Civil Engineering Building, Purdue University, phone (317) 494-5034.

Respectfully submitted,

Harold L. Michael /d

Harold L. Michael, Director
Joint Highway Research Project

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INTRODUCTION

to

SLOPE STABILITY ANALYSIS

WITH STABL4

by

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INTRODUCTION

STABL is a computer program for the general analysis of slope stability by a two dimensional (2-D) limiting equilibrium method. The program uses the method of slices to analyze the slope and calculates the factor of safety (FOS) according to the simplified Janbu or Bishop methods for non-circular and circular surfaces, respectively. A unique feature of the program allows random surfaces to be generated, allowing the user to determine the critical, minimum FOS more easily.

DEVELOPMENT OF STABL

The 2-D computer program STABL was developed at a time when most highway agencies analyzed slope stability using two common techniques: computer-aided, grid-type circular searches; and block analyses for simple and specified surfaces. Circles were often assumed to be the appropriate shape for potential failure surfaces simply because there was no other shape which could be used for computerized searching.

In the last decade, improvements in 2-D slope stability analysis have proceeded in several directions; one of these is contained in STABL, in the form of computerized searching with non-circular shapes. The non-circular routines RANDOM and BLOCK were first reported by Siegel (1975a) as well as a random (as opposed to a grid) type search with circles (CIRCL2). Favorable comparisons of the FOS values generated by STABL with those for the same surfaces by other methods of slices were reported by Boutrup (1977).

STABL was placed on line for routine use in 1976 by the Indiana Department of Highways (IDOH), and after being reported in the open literature (References 11, 2, 3, 4, 12), the program began to be adopted by many agencies. STABL has been modified in minor ways over the past eight years, and users of the program have helped greatly in debugging operations. The present version of STABL is called STABL4.

CAPABILITIES OF STABL

STABL is the only known program to contain searching routines for shapes other than circles. Circular grid search routines are common; STABL searches by generating circles, with randomly selected radii and centers limited by user-defined parameters as explained later. A number of programs can determine the FOS for any specified non-circular shape, but only STABL can both generate general shapes and determine their FOS values.

The 2-D program uses a simplified method of slices and thereby minimizes iterative procedures in the solutions. The single limitation on boundary geometry is that there be no vertical or overturned ($>90^{\circ}$) surfaces. Subsurface boundaries may demonstrate any degree of natural complexity, and up to ten piezometric surfaces may be specified. Also, options allow boundary and pseudo-static earthquake loadings to be considered in the analysis.

The circular potential sliding surface is appropriate when the subsurface materials are grossly homogeneous and isotropic. Block-type surfaces are probable when weak strata are present, and the critical surfaces tend to have a maximum length within these strata. Thus, we have

cited two cases in which simplifying assumptions are appropriate. In the first case it is proper to assume a circular shape and iterate for the position of the critical surface. In the second case, the positions of the major portion of the sliding surface may be assumed, but the entry into the weak layer, the length of sliding surface in this layer, and the departure from it need to be iterated.

A far more common occurrence is the profile where neither shape nor position may be safely assumed and the analysis should both generate and compute FOS values for a wide variety of shapes and positions. The non-circular surface generating routine RANDOM is well suited to this requirement.

In using the searching routines CIRCL2, BLOCK (BLOCK2), and RANDOM, the positions of the surfaces are not obvious. With RANDOM, the shape generated is a further uncertainty, and plotting routines which resolve both uncertainties are necessary. These routines can both show the sub-surface space searched and the portion of that space occupied by the more critical surfaces.

COMPUTER REQUIREMENTS

STABL is written in FORTRAN IV and has been successfully used on the following computer systems:

1. CDC 6500-6600

2. IBM 360/370

3. VAX 11/780

With some modifications, STABL may also be converted for use on a micro-computer (Ref. 10). However, the versions available from Purdue University should be compatible with most systems which can compile the FORTRAN IV language.

On the CDC system, the program requires a field length of approximately 70,000 to 80,000 words for storage and execution. The CPU time for "average" runs is generally 16 to 32 seconds for approximately 100 circular surfaces and may be up to 128 seconds for 100 irregular surfaces. However, the cost of each run is directly proportonal to the complexity of the surface and sub-surface geometries and will be a unique feature for each individual analysis.

DESCRIPTION OF STABL

Assumptions

STABL assumes that the instability to be prevented would be two-dimensional. In reality, all sliding failures must be 3-D, with the end/edge resistance furnishing additional safety against instability. For more quantitative information on the comparison of $(FOS)_{3D}$ to $(FOS)_{2D}$, see Chen (1981) and Lovell (1982). In general, $(FOS)_{3D} > (FOS)_{2D}$, but the difference may be small, and in certain special cases $(FOS)_{2D} > (FOS)_{3D}$. Where the stability problem is perceived to be definitely 3-D, the engineer is encouraged to use the BLOCK3 or LEMIX codes of Chen (1981).

STABL uses simplified methods of slices for determination of FOS. The alternative requires solutions with extensive iteration and the consequent problems of nonconvergence in these iterations. Boutrup (1977)

has shown that the simplified methods after Janbu and Bishop give reasonably precise values of FOS.

Agencies staffed with appropriate mathematical and software skills can insert any desired slices solution into the program...simplified or total equilibrium. STABL is a stability analysis system, of which the method of slices detail, is a small part.

The selection of a center of moments for the slices analysis is an intriguing point. In the simplified approaches, the free body is not iterated into equilibrium, and accordingly, the FOS value is peculiar to the center selected. This is true even for the circle, where the circle center is arbitrarily selected in the simplified Bishop method. For other shapes, there is usually no "center" to select for moments. After much study of this question (Carter, 1971; Siegel, 1975a, Boutrup, 1977), the circle center is used for CIRCL2, and a very long moment arm is used for BLOCK, BLOCK2, and RANDOM. The latter choice means that these noncircular surfaces are analyzed with the same slice assumptions as the simplified Janbu method.

Both of these slices methods contain the FOS value in implicit form, which requires an initial iteration for FOS. This iteration is greatly expedited if it is entered with a reasonable value of FOS. This can ordinarily be accomplished by means of a Taylor type chart (Reference 13), where the real problem has been suitably simplified to permit approximate chart solutions.

STABL values may be checked for a specific failure surface in several ways. CIRCL2 should yield about the same FOS (for the same

circle) as any other computerized analysis for circles. To determine that this is indeed the case, the new user of STABL can run CIRCL2 in parallel with his present method. BLOCK or BLOCK2 can be checked approximately (for a specific block) either manually or perhaps by existing charts. RANDOM is amenable to approximate manual checks.

Input Options

Numerous options are available for use with the STABL program according to the user's specific requirements. These options are defined by command words (e.g., PROFIL, EQUAKE, etc.) for easy recognition, especially when checking input data. Different commands activate or deactivate different portions of the program, which also allows the user to control and perform the analysis economicaly. Generally, these commands may be categorized into four major divisions:

1. Surface and subsurface geometry, with command words

    PROFIL

    LIMITS

2. Subsurface profile parameters, with command words

    SOIL

    ANISO

    WATER

3. Boundary loads, with command words

    LOADS

    TIES (Available in STABL4 only)

    EQUAKE

4. Analytical methods, with command words

    SURFAC/SURBIS

CIRCL2

RANDOM

BLOCK

BLOCK2

The command PROFIL is used to label input data of the slope geometry and any subsurface boundaries forming the soil strata. Up to one hundred different boundaries can be specified. If the user is trying to confine critical surfaces within certain zones, the command LIMITS may be used. This prevents the generation of critical planes beyond the defined limiting boundary, such as competent rock underlying the slope. Of course, one could simply introduce the rock as a soil type with a high strength, which would effectively lead to higher factors of safety (FOS) for surfaces passing through the rock. However, the LIMITS option, by eliminating the surfaces which would have passed through the rock, is more efficient since computer time is not wasted in computing a high FOS. Additionally, an upper limiting boundary, which will force planes downwards, may also be specified. This is useful for stability analysis of retaining structures such as sheet piles, anchored bulkheads, reinforced earth walls, etc.

In order to define subsurface conditions, the command SOIL is used to assign for up to 20 soil types the soil parameters which include unit weights, $c-\phi$ parameters and pore pressures. If the user feels that the strength properties are significantly anisotropic, the command ANISO allows one to define the strength parameters in up to 10 sectors, the appropriate values being selected according to the plane of interest. The WATER option is used to define up to 10 different piezometric levels

within the slope geometry. These can be successfully used to assign perched water tables and also to simulate pore pressure distributions within the soil strata.

External boundary loads which may be applied to the slope are defined by the command, LOADS. This allows input of up to 10 loads, as a surcharge intensity, in any direction. A boundary load of varying intensity may be approximated by a set of equivalent uniformly distributed loads abutting each other. Tieback or concentrated loads applied to the slope are defined by the command, TIES. This option allows input of up to 10 horizontal or inclined concentrated loads applied to the profile surface. The TIES option is fully described in Appendix F and is available only in the most recent version of STABL, STABL4. For a pseudo-static earthquake analysis, the command EQUAKE is used to assign vertical and horizontal coefficients to simulate the design earthquake.

Four different methods of analyzing the stability of a slope are available for use in STABL. The commands SURFAC (for Janbu Analysis) or SURBIS (for Bishop analysis) are used for determining the FOS for a specific critical failure surface defined by coordinates input by the user. However, if the user is at an initital investigation phase, the commands RANDOM (irregular surfaces) and CIRCL2 (circular surfaces) may be specified to utilize the program's unique capability to generate critical failure surfaces in a random manner. The user only needs to define the initiation and termination limits of the failure surfaces. If block-type analysis is also required, the BLOCK or BLOCK2 options allow the user to generate random blocks for analysis. For these

blocks, the user can manipulate the size of the block zones to arrive at the minimum FOS.

Thus, by specifying the geometry and soils of the slope, the user can perform numerous operations, using three different types of critical failure surfaces, to arrive at the most probable value for the FOS for the slope. Additionally, all the commands, except for PROFIL and the analysis commands, may be turned "off" or "on" which allows use of the same input data for the entire stability analysis, without having to create multiple data sets.

Data is input as "free-format", beginning in the first column (left justified), with items being separated by one space. This facilitates data entry as it does not restrict the user to certain column widths which sometimes lead to format errors. Also, STABL is compatible with any unit systems which the user may prefer to utilize for analysis. Providing consistent units of length and mass are used, the program will function without error. For example one may use the following:

Coordinates:	feet (ft)	metres (m)
Unit Weights:	pounds/cubic foot (pcf)	kilograms/cubic metre (kg/m^3)
Strength Intercept:	pounds/square foot (psf)	kilograms/square metre (kg/m^2)
Pore Pressure:	pounds/square foot (psf)	kilograms/square metre (kg/m^2)
Unit Weight of Water:	62.4 pcf	1000 kg/m^3

Searching Routines

Each slope to be analyzed is made left-facing and placed in a first quadrant position so that all coordinates will have positive values. In order to make the computer generation and search reasonably efficient, a number of restrictions are placed on the surfaces:

(1) They should enter and exit the surface boundary at reasonable positions. This is accomplished by assigning initiation and termination limits. See Figure 1.

(2) They should not go deeper than a depth limit, usually represented by a hard layer. See Figure 1.

(3) They should be composed of straight line segments, not so long as to fail to represent real changes in surface shape, and not so short as to produce "kinkyness" in shape. Guidelines have been worked out through experience.

(4) The generated surfaces shall appear to be kinematically acceptable, i.e., when examined, movement along them appears logical.

(5) While surfaces are generated in a random fashion, there must be some bias inserted to obtain acceptable shapes.

Figure 2 shows schematically how the first line segment is generated. Without appropriate upper and lower limits, the surface could immediately assume an illogical shape and position. The direction of the first line segment is determined within the limits by a random number generator in the program. As shown in Figure 3, the second seg-

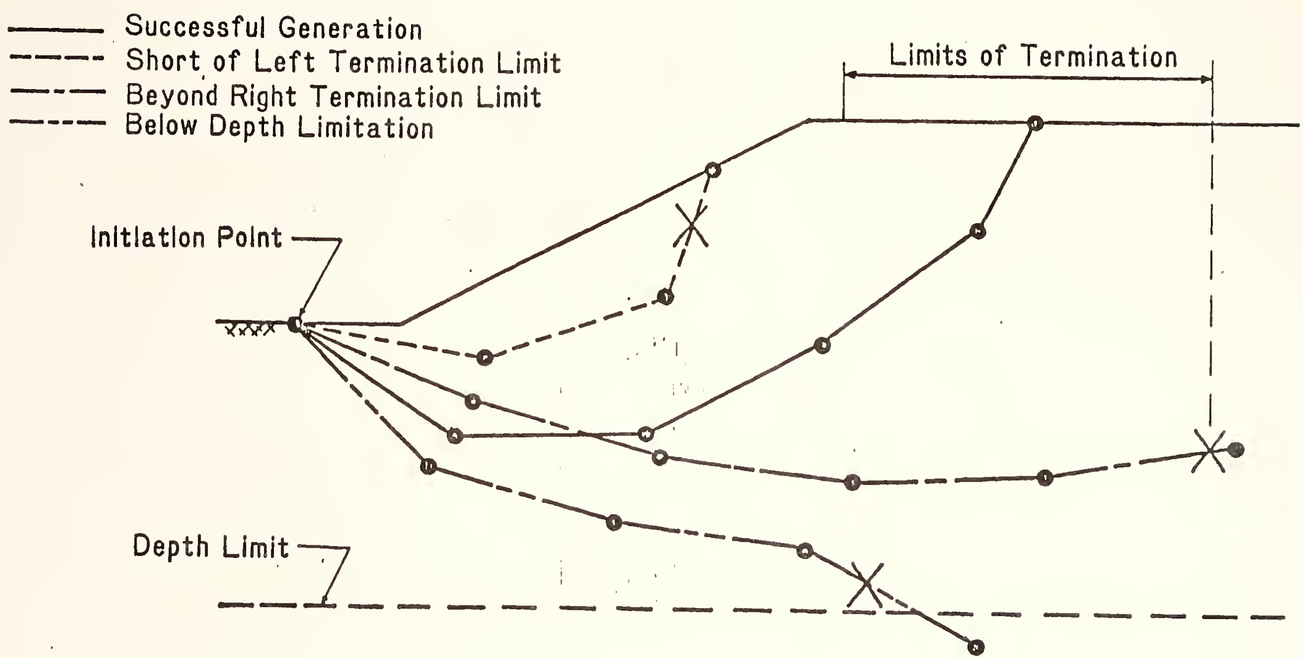

FIGURE 1. TRIAL FAILURE SURFACE ACCEPTANCE CRITERIA

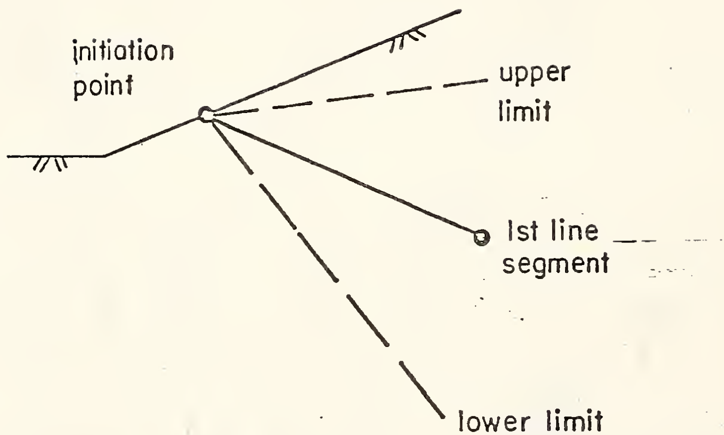

FIGURE 2. GENERATION OF FIRST LINE SEGMENT

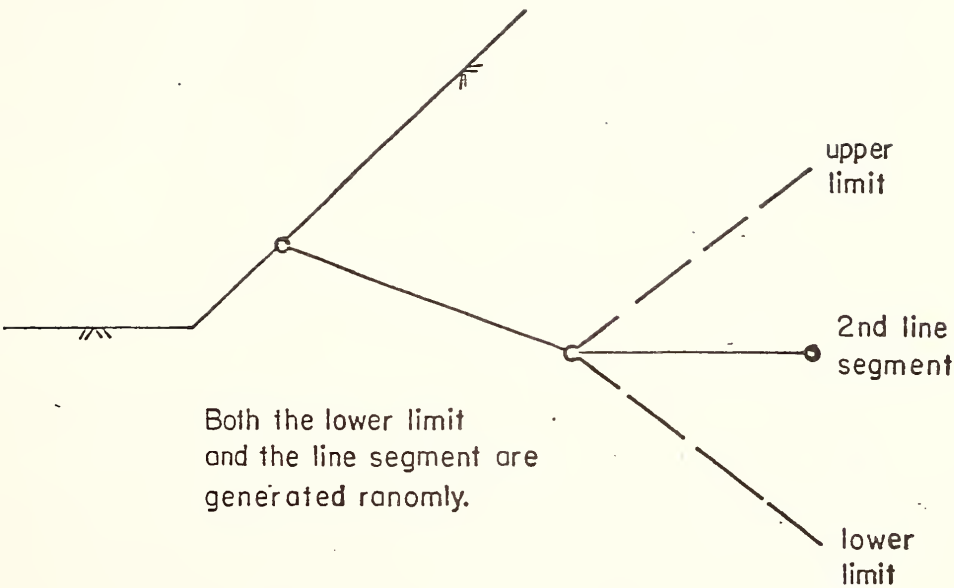

FIGURE 3. GENERATION OF SECOND LINE SEGMENT

ment of the potential failure surface has an assigned upper limit and a lower limit which is generated in a random but somewhat biased direction. The direction of the segment is again randomly generated within the limits.

If a circle is being generated (CIRCL2), it has been defined by the random generation of the first two segments (chords). The program will complete the generation of the circle and determine its FOS. For the irregular surface generation (RANDOM), random choices continue to be made as for the second segment until the surface is totally generated; it is then analyzed for the FOS.

Some surfaces will violate the depth or termination limits (Figure 1) and will be discarded. Surface generation is accomplished in a batch mode, with the generation continuing until the desired number is accomplished, or until a large number of attempts have been made without total success.

The searching procedures described above are appropriate for CIRCL2 and the RANDOM, but may not be economical where weak layers govern the location of critical sliding surfaces. In such cases, grided "boxes" are superimposed on the weak layers. As shown in Figure 4, boxes are specified to overlie a weak layer wherever that layer changes in direction.

Points are randomly chosen within the specified boxes, and connected by straight lines. The surfaces are completed at the ends by random generation (BLOCK) or by assuming that these ends are simple Rankine type surfaces ($45 \pm \frac{\phi}{2}$), as in BLOCK2. The routine BLOCK is

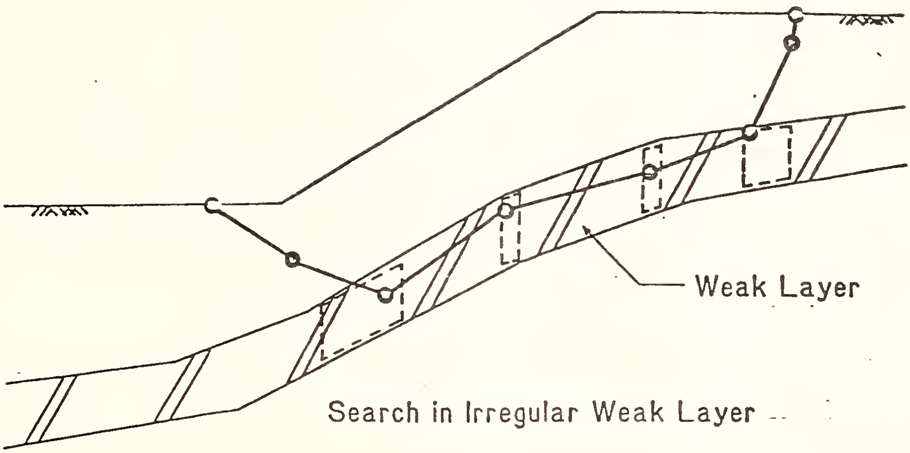

FIGURE 4. SLIDING BLOCK GENERATOR USING MORE THAN TWO BOXES

illustrated in Figure 5, where the random limits cause the active side segments to be $>-45^{\circ}$, and the passive side segments to be $<-45^{\circ}$. BLOCK2 is somewhat simpler than BLOCK, and has tended to be used more. Since the boxes can degenerate to points or lines, the program can be used for cracks, joints, or fissures.

As emphasized further in the next section, interaction between searching routines and plotting routines is required. When arbitrary assumptions are made with respect to selection of a searching mode, initiation zone, termination zone, depth limit, box position and the like, the plotting routines have a capability to reveal this.

Plotting Routines

The use of plotting routines is essential to the random generation of surfaces in STABL. These plots will indicate: the shapes generated; the subsurface space searched; and the positions of generated surfaces which have the lower values of FOS. Surfaces are generally generated in batches.

The plot of all surfaces in a batch which involved 10 irregular surfaces from each of 5 initiation points is shown in Figure A2 in Appendix A. Also, an accompanying plot, which depicts ten critical surfaces with the lowest FOS, is shown in Figure A3. Depending upon the practical problem involved, the engineer may decide to change the initiation limits, terminiation limits, or depth limits to "explore" other areas for a more critical surface. He may even decide to use different generation modes, i.e., BLOCK (BLOCK2) or CIRCL2.

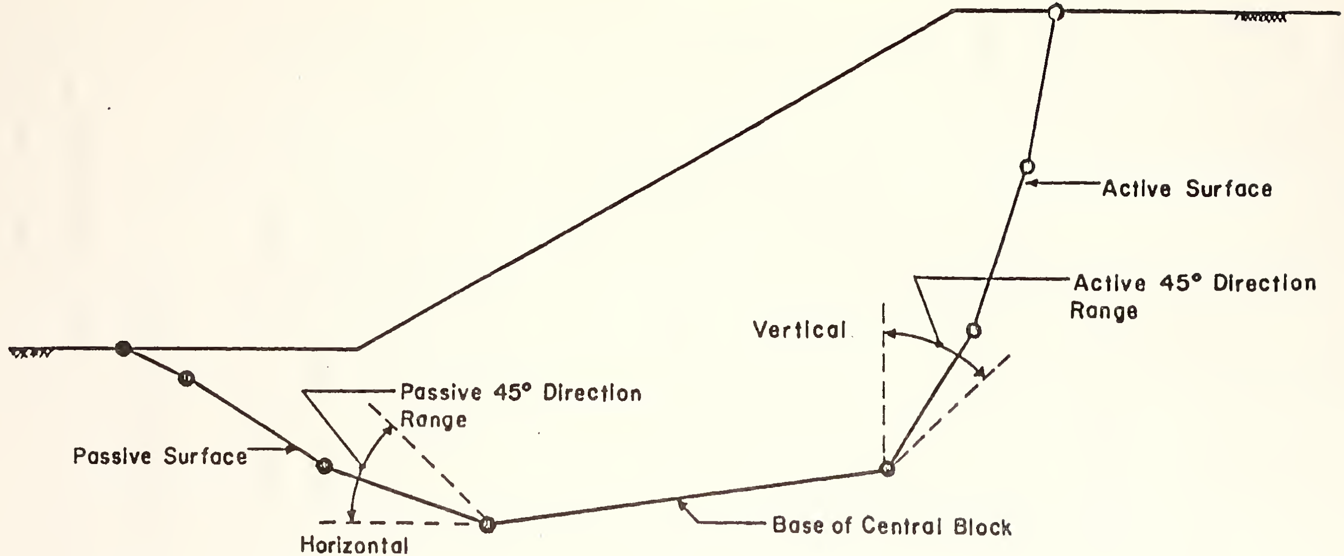

FIGURE 5. GENERATION OF ACTIVE AND PASSIVE SLIDING SURFACES USING BLOCK OPTION

In any reasonably complex problem, multiple man-machine interactions are required, and are anticipated in the procedures of STABL. The engineer should avoid promising the final results of an analysis based upon the computer "turn around" time for a single run.

Error Messages

In a comprehensive program such as STABL it is likely that errors will be committed in data/analysis input and commands. Most data errors will be detected by the program and the user is notified by an error message and a print-out of the line of erroneous data. These error messages are documented in the User Manual (Ref. 10), and allow the user to quickly correct mistakes with a minimum amount of time spent searching the input data. Additionally, data are checked and verified continuously during execution of the program to minimize the risk of incorrect or misleading output.

Recent Changes

Appendices E and F contain modifications effected in STABL during the past year. One of these is a change in the pseudo-static earthquake option, which eliminates the increase of pore pressures for an effective stress analysis. Appendix F contains an improvement which makes it more convenient to use near-horizontal boundary forces, such as those produced by tiebacks.

COMPARISON WITH OTHER PROGRAMS

This topic has been approached in two ways (Siegel, 1975a; Boutrup, 1977). The first is to simplify the problem in terms of boundary and

subsurface conditions, and to compare values of minimum FOS generated by searching with a variety of available programs. Since only STABL searches with shapes other than circles, the comparison comes down to values generated by the various circular methods of slices. The Geotechnical Engineering literature contains many such comparisons, which show that the simplified Bishop assumption used in CIRCL2 compares well with the longer and more iterative total equilibrium approaches. Research at Purdue shows the same results.

A second approach is to generate critical surfaces, in relatively complex problems, by using the non-circular searching modes in STABL. This is followed by generating FOS values, for the specific surface defined by STABL, by other available methods. Putting aside the probability that the engineer would fail to find the most critical surface by specifying possibility after possibility, the simplified Janbu approach of STABL gives somewhat conservative (low) values of FOS.

It is well to remember two facts relative to comparisons. Firstly, there is no analysis method which gives the correct value for FOS for reasonably complex problems. Since there is no method for determining the true answer, there is no way of assigning errors to any practical method. Secondly, comparisons vary with the part of the data field being examined, i.e., relative values change with the specific set of examples.

Neither of the two difficulties discussed above need perplex the engineer using STABL. When STABL is being considered as a replacement

for extant methods, they can be run in parallel with each other, and answers compared.

SUMMARY

The STABL slope stability system allows computerized searching for a variety of shapes for potential sliding surfaces. All such surfaces are represented as a series of straight lines, and the line directions are chosen in a pseudo-random manner. The analyses proper use simplified Bishop or simplified Janbu methods of slices to determine FOS values.

Plotting routines are necessary to assess the exact shapes and positions of generated sliding surfaces and to determine whether it is probable that the more critical sliding surfaces have been generated and analyzed. Error messages allow checks on input and execution steps.

The STABL system should be entered with reasonable estimates of the minimum FOS, so that iteration of the implicit expressions for FOS is minimized. The estimates may be obtained from existing chart solutions of the real problem in simplified form. The CIRCL2 searching option in STABL should yield values of FOS which compare closely with those of other circular searches. The BLOCK and RANDOM options in STABL are likely to produce somewhat lower values of FOS than specific surface analyses by other methods. One reason for this difference is the probability that a limited number of specific surfaces will not identify the critical sliding surfaces. The STABL searches should do a reasonable job of accomplishing this objective.

The latest documentation relating to STABL is presented in Appendix B. Appendices E and F contain recommended changes in the program with respect to the earthquake option, and the convenient entry of near-horizontal tieback forces into the calculations of FOS.

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APPENDIX A

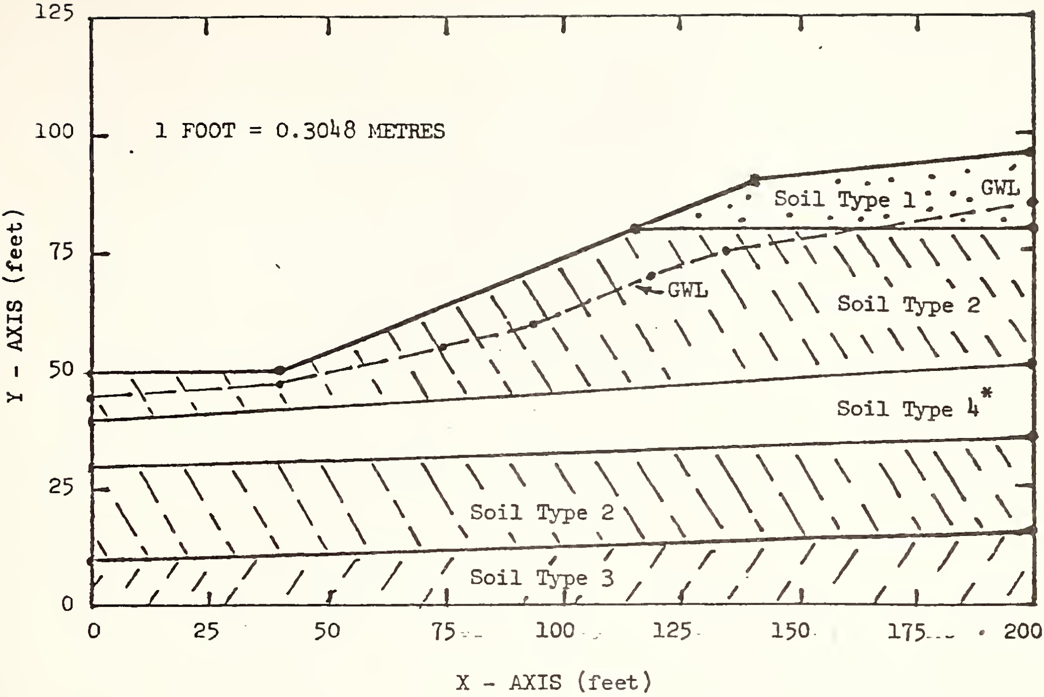
EXAMPLE PROBLEM

The stability of the slope shown in Figure A1 was investigated using STABL. The example subsurface profile consists of 3 soil types for the irregular surface and circular surface analysis. For the block analysis, a "weak" seam was introduced, as soil type 4, to illustrate this option. A high groundwater level was assigned to the slope.

The irregular surface search was confined to zones where the randomly generated surface would initiate and terminate between x = 25 to 45 ft (7.62 to 13.72 m) and x = 140 to 185 ft (42.67 to 56.39 m), respectively. The 50 surfaces which were successfully generated between these user-defined limits are shown in Figure A2. A summary of the ten most critical surfaces is shown in Figure A3 with the surface representing the minimum factor of safety being "highlighted" with asterisks (*).

A similar search was also performed for 50 circular surfaces with the same initiation and termination limits as used for the irregular surface search. The 50 surfaces are shown in Figure A4 and the summary in Figure A5.

The "weak" seam, which was introduced into the subsurface profile, usually leads to failure represented by block or wedge shapes. The central portion of the block failure was limited between the two boxes, judiciously placed, to "force" generation of block surfaces along the "weak" layer. As can be seen from Figure A6, the major portion of all



*stratum consisting of Soil Type 4 was used for the 'block' analysis, only.

Figure A1 Example Slope Geometry and Subsurface Profile

Table A1 Summary of Soil Properties Used in Example

Soil Type #	Total Unit Wt. (pcf)	Sat. Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)
1	125.0	129.0	0.0	38.0
2	120.0	127.0	400.0	21.0
3	128.0	132.0	600.0	26.0
4	124.0	128.0	200.0	16.0

For S.I. conversion, use :

1 psf = 47.873 Pascals (or 4.882 kg/sq. metre)

1 pcf = 16.018 kg/ cubic metre

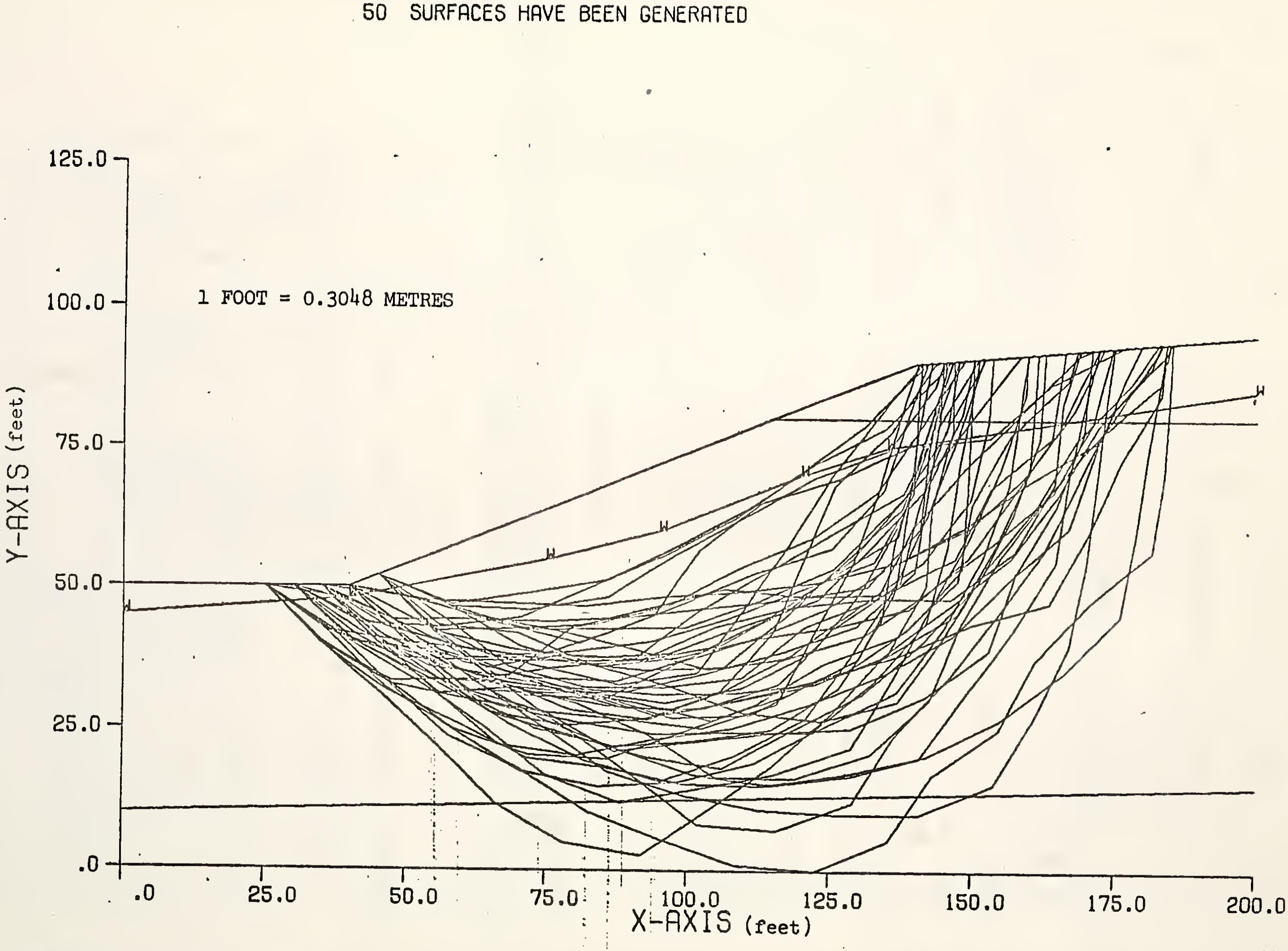


Figure A2 Irregular Surface Search

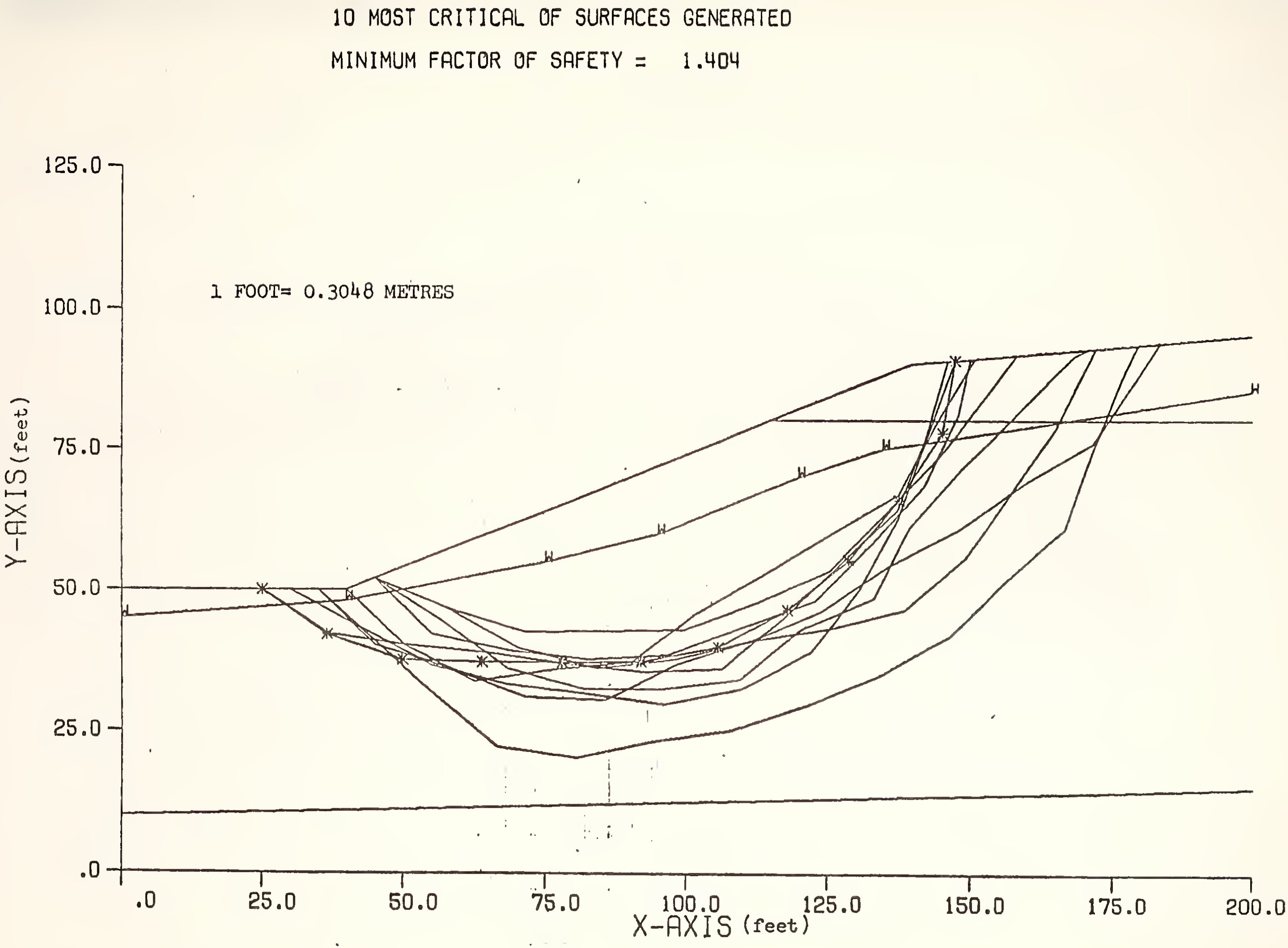


Figure A3 Ten Most Critical Surfaces, Irregular

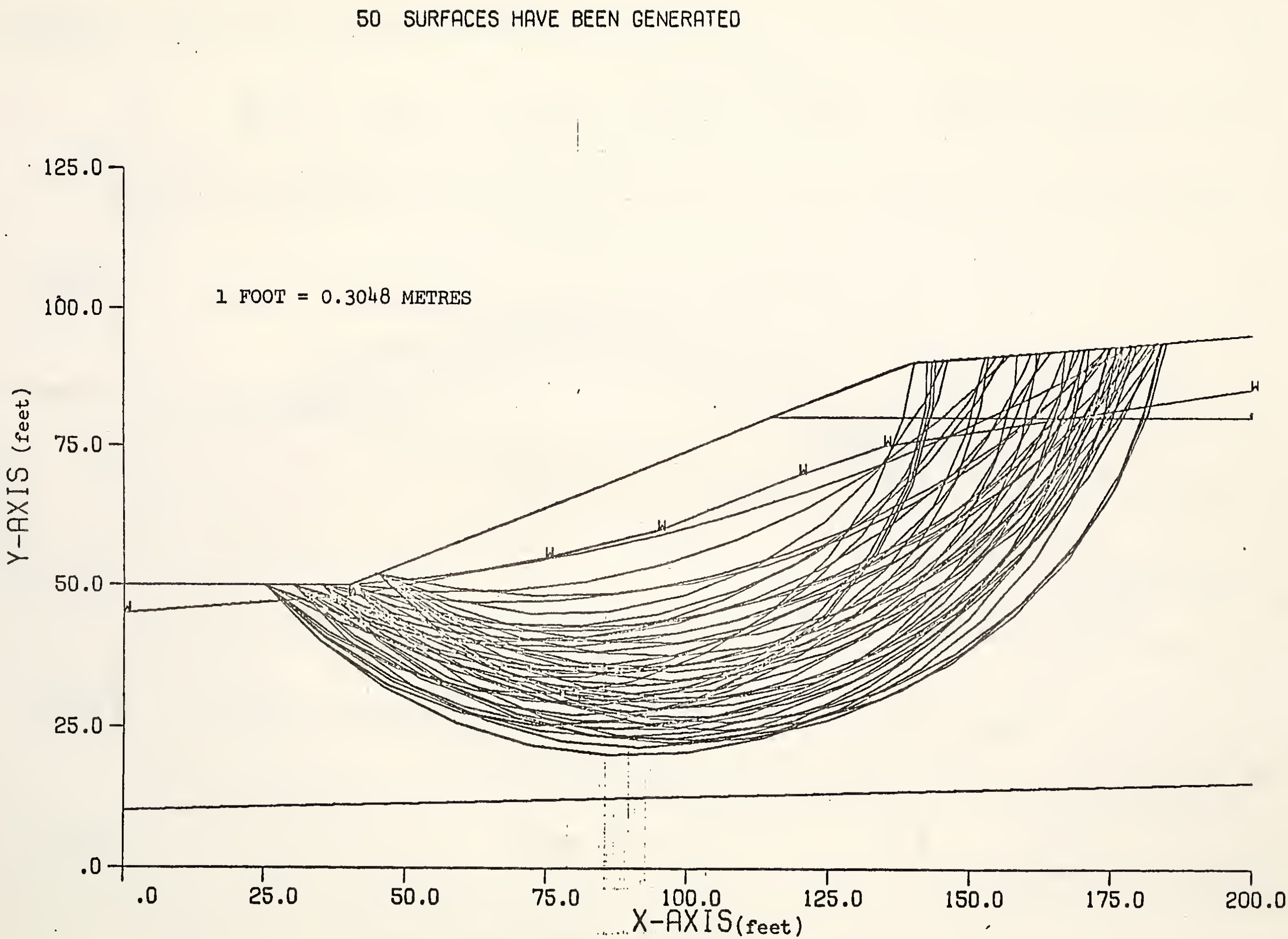


Figure A4 Circular Surface Search

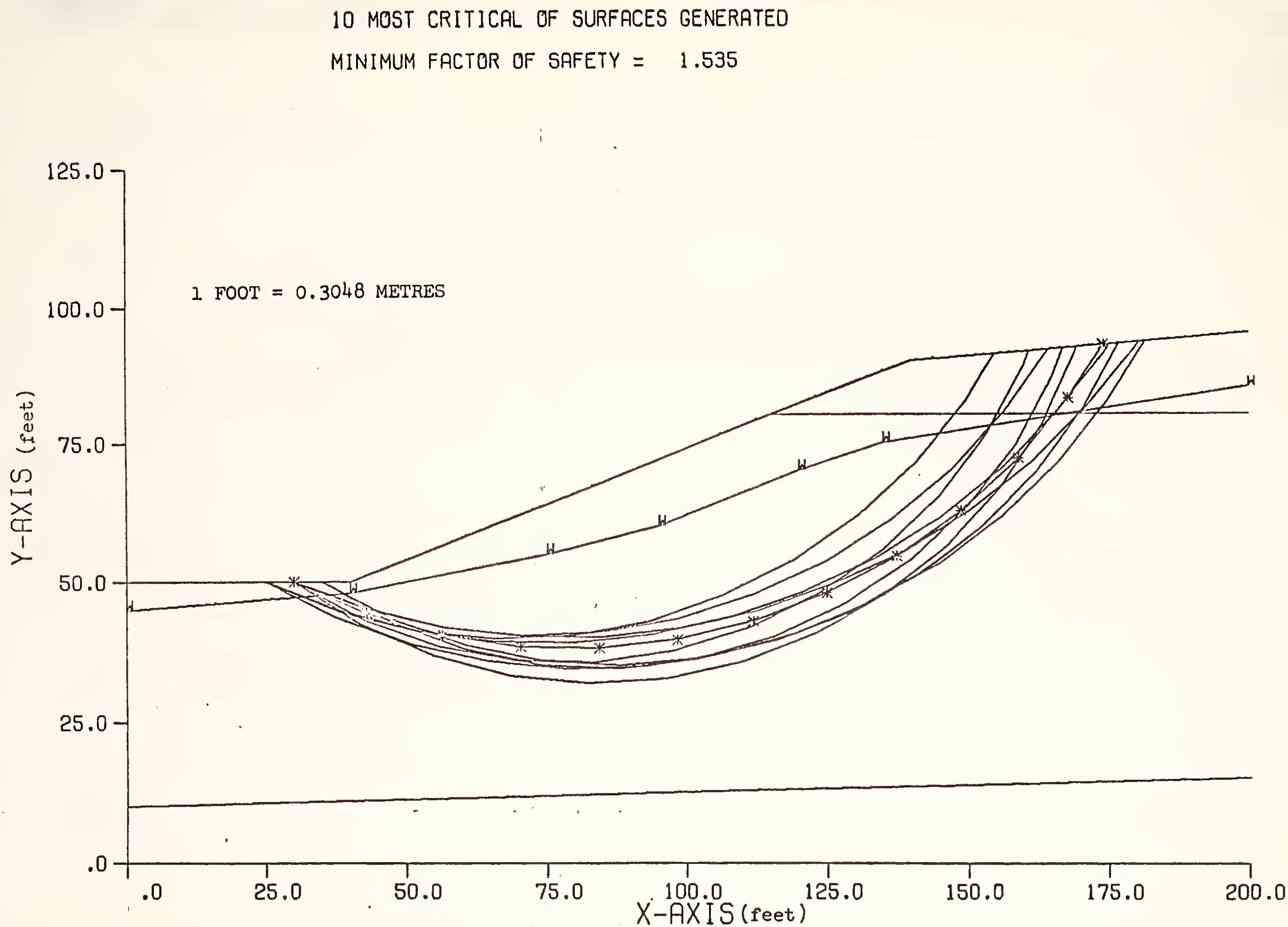


Figure A5 Ten Most Critical Surfaces, Circular

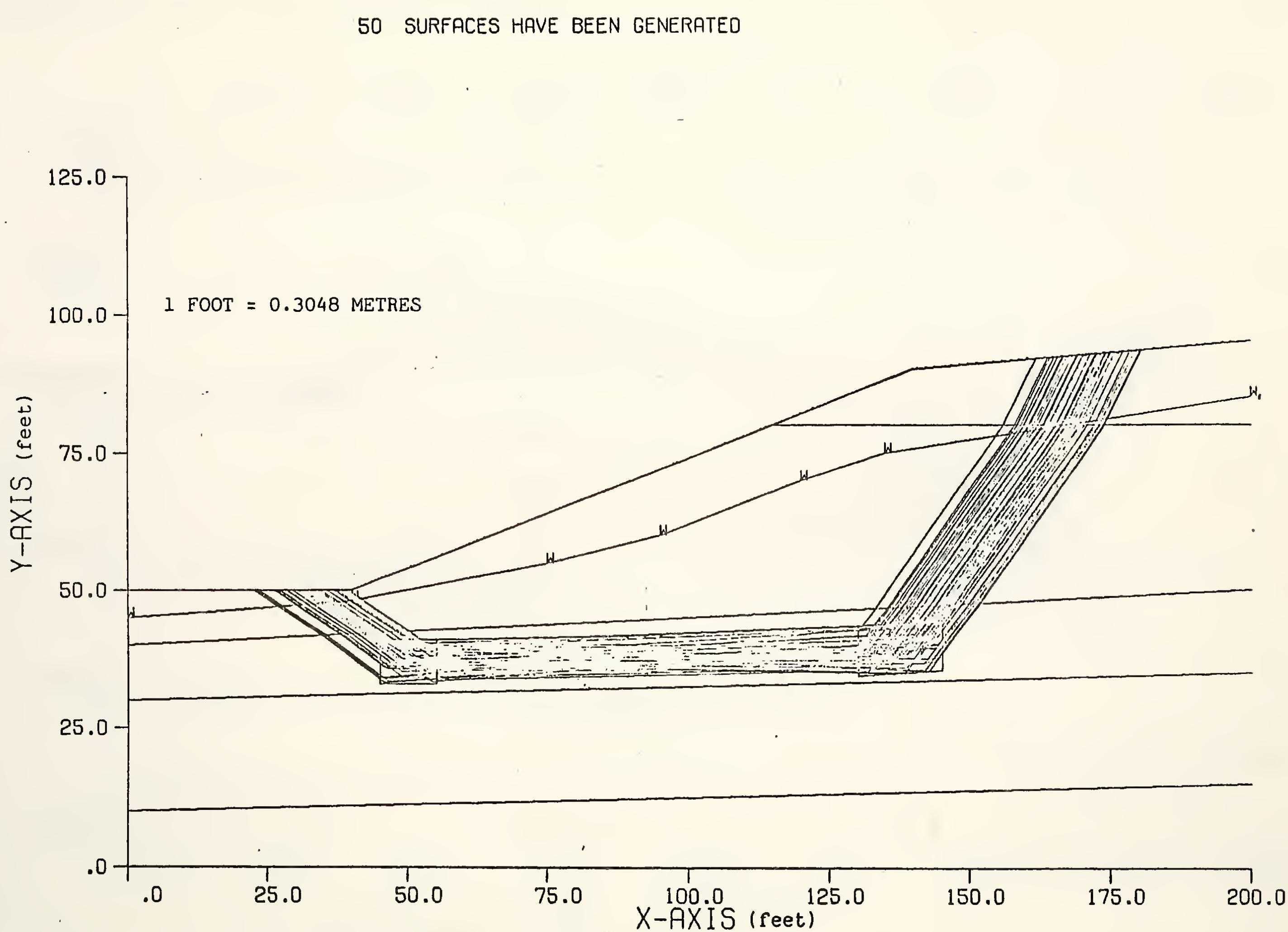


Figure A6 Block Surface Search

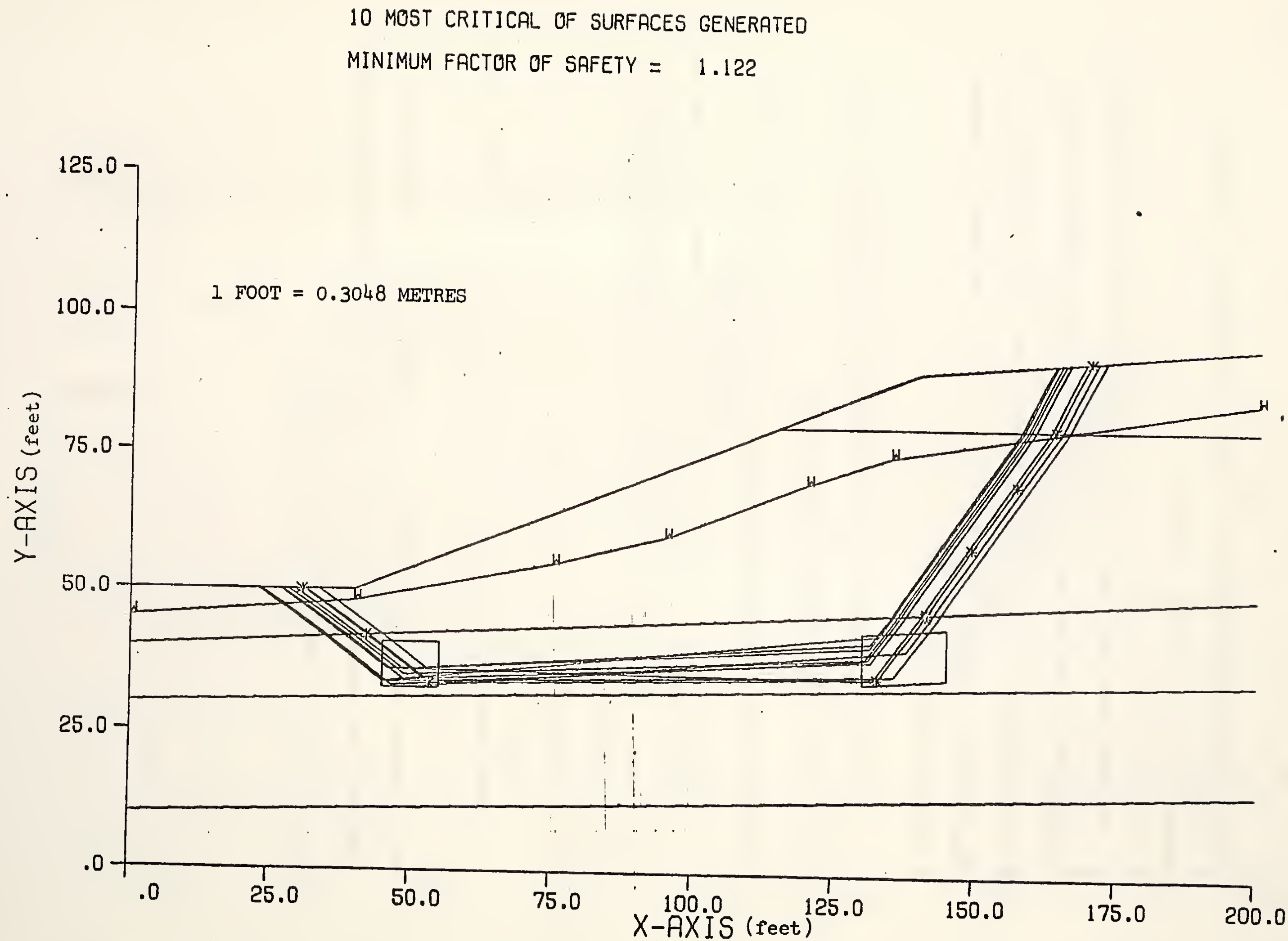
block surfaces was confined to the "weak" layer. Figure A7 presents a summary of the most critical surfaces.

The three most critical irregular, circular and block surfaces were also analyzed further for earthquake loads. Seismic coefficients with a value of 0.02 were used with the vertical loading being downwards and the horizontal loading outwards from the slope. The change in factors of safety are shown in Figures A8 to A10.

Thus, based on a first run, we can summarize the minimum factors of safety for different critical surface types:

TYPE OF CRITICAL SURFACE	FACTOR OF SAFETY	
	STATIC CASE	EARTHQUAKE LOADS
Irregular	1.40	1.30
Circular	1.54	1.42
Block	1.12	1.03

After one has examined the output of the initial run, the user can evaluate the extent of the search for the "most" critical surface and decide if further investigations are required.



<u>Figure A7</u> Ten Most Critical Surfaces, Block

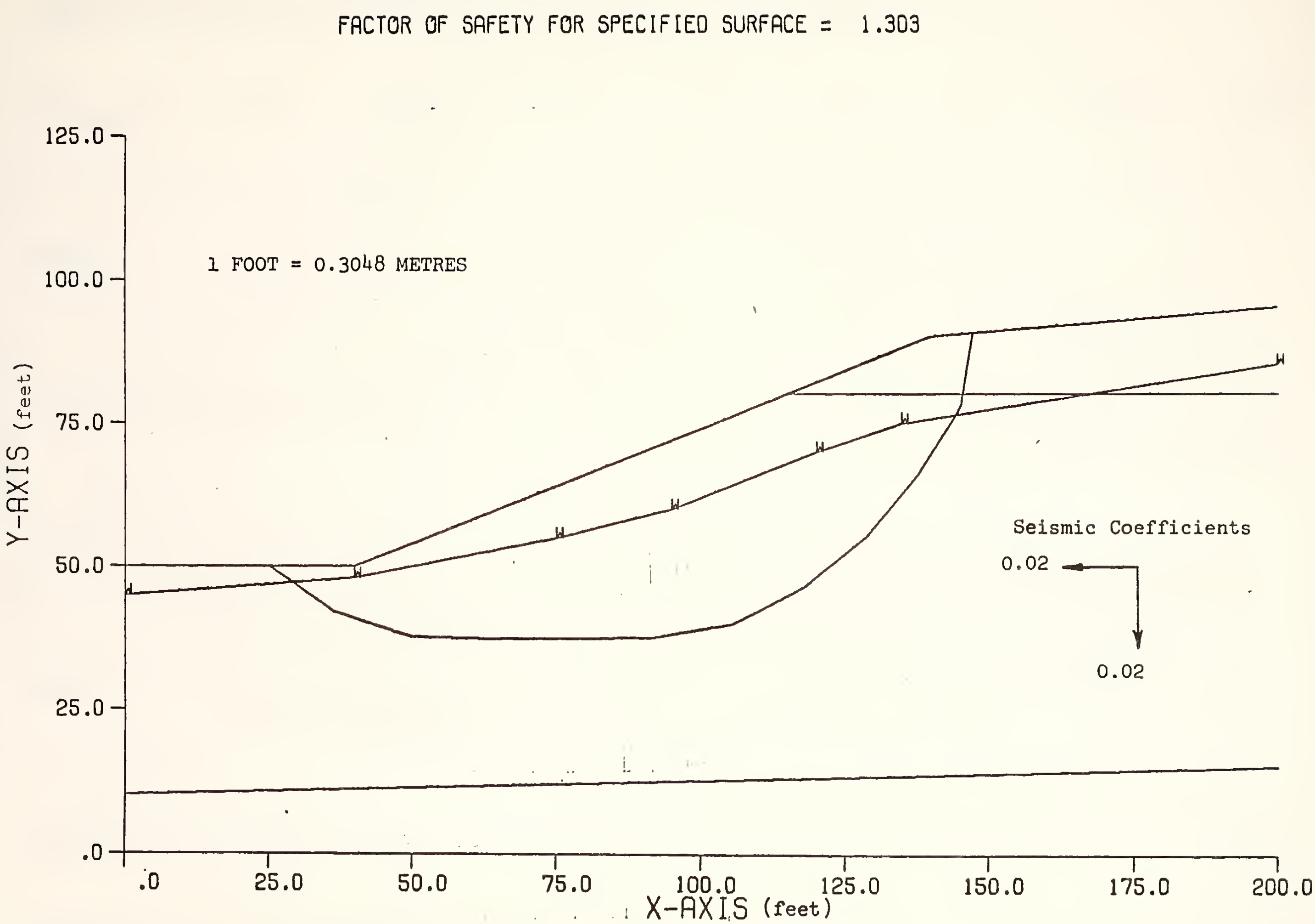


Figure A8 Pseudo Earthquake Analysis of Most Critical Irregular Surface

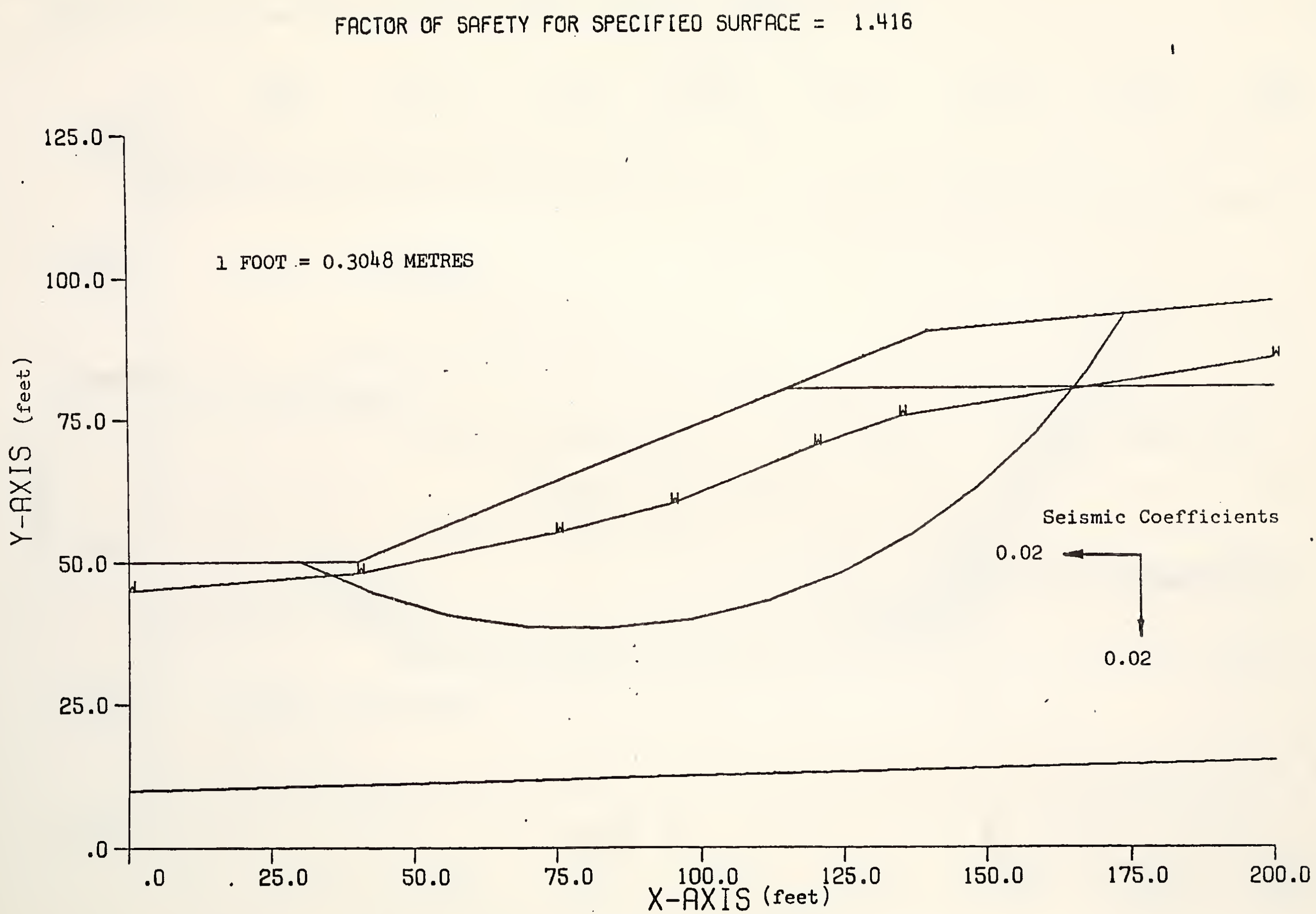


Figure A9 Pseudo Earthquake Analysis of Most Critical Circular Surface

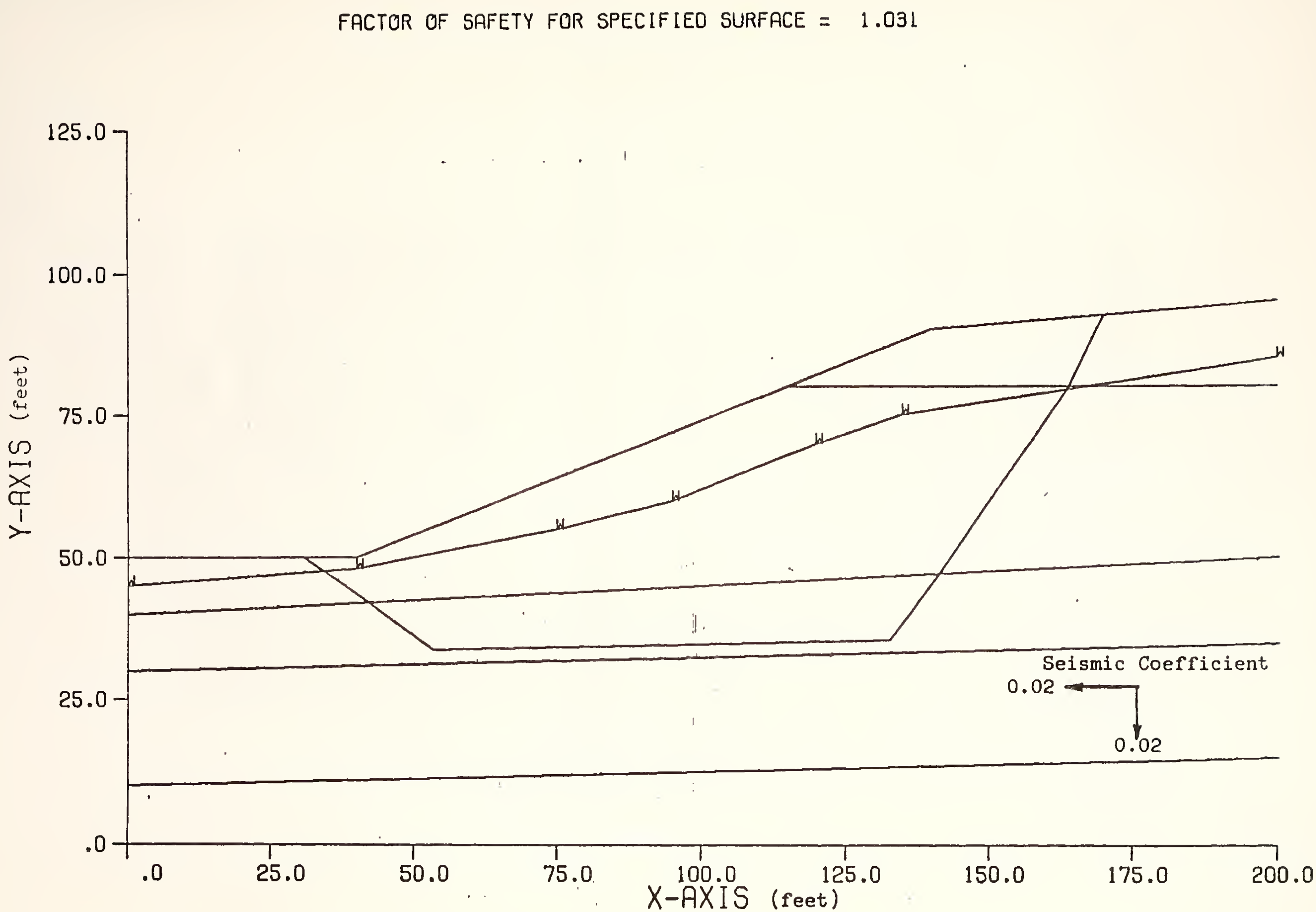


Figure A10 Pseudo Earthquake Analysis of Most Critical Block Surface

APPENDIX B

STABL DOCUMENTATION

1. STABL Program, available on unlabled 9-track tape for IBM or CDC Fortran codes at the required:

    1. recording density, in bpi

    2. fixed block size (URL=80)

    3. conversion format (EBCDIC or ASCII)

2. Listing of program

3. STABL User Manual, JHRP-75-9

4. Computer Analysis of General Slope Stability Problems, JHRP-75-8

5. Computerized Slope Stability Analysis for Indiana Highways, Vol. 1, JHRP-77-25

6. Vol. 2 (1977 Program Listing), JHRP-77-26

7. Three-Dimensional Slope Stability Analysis, JHRP-81-17

For ordering or further information, please contact:

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APPENDIX C

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   Bureau of Materials and Research
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   Phone: 404-363-7567

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   Topeka, Kansas 66612
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14. State of New Mexico Highway Department
Bureau of Materials
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16. Oklahoma Department of Transportation
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Oklahoma City, Oklahoma 73105
Attn : Charles Whittle
Phone:

17. Oregon Department of Transportation
Bridge Section
Oregon DOT Building
Salem, Oregon 97310
Attn : John Marks
Phone: 503-378-6551

18. Texas State Department of Highways and Public Transportation
11th and Brazos
Austin, Texas 78701
Attn : Mr. Wayne Henneberger
Phone:

19. Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101
Attn : Chien-Tan Chang
Phone: 703-285-2357

20. Utah Department of Highways
4501 South 2700 West
Salt Lake City, Utah 84119
Attn : Loren Rausher
Phone: 801-965-4196

21. Washington State Department of Transportation
    Materials Laboratory
    P. O. Box 167
    Olympia, Washington 98504
    Attn : Leroy Wilson
    Phone: 206-753-7100

22. Wisconsin Department of Transportation
    3502 Kinsman Boulevard
    P. O. Box 7878
    Madison, Wisconsin 53704-7878
    Attn : Gary Whited
    Phone: 608-246-3249

23. Wyoming Highway Department
    Cheyenne, Wyoming 82002
    Attn : Bill Sherman, Chief Engineering Geologist
    Phone: 307-777-7801

APPENDIX D

COMMENTS ABOUT SAFETY FACTORS FOR SAMPLE PROBLEMS

Some concern has been expressed about the discrepancy between the safety factors given in the User Manual for the sample problems and those computed by the Users. These differences are due to use of STABL on non-CDC computers and thus, we would like to offer an explanation for these variations.

The factors of safety, for surfaces generated using random numbers, will depend somewhat on the sequence of such numbers and the method of computation. The example problems presented in the User Manual were analyzed on a CDC computer, using a library function to generate the required random numbers. The library function available for VAX computers will provide the same sequence of random numbers. Thus, the results shown in the example problems may be duplicated only if the program is executed on a CDC or VAX computer. For other cases (e.g., IBM computers), the function, RANF, within the program source code is used to generate the sequence of random numbers. However, since such a sequence of random numbers will be different from the one generated by a CDC or VAX library function, different potential failure surfaces will be analyzed by the program. Consequently, a different minimum factor of safety will be computed and the critical surface will differ somewhat from the one presented in the examples.

APPENDIX E

MODIFICATIONS AND REVISIONS OF STABL

Some additional changes have been made in the last 18 months, due to a much more extensive use of STABL for teaching purposes and also as a result of interaction between the Users and Purdue University. Most of these changes are minor and only improve the operation of the program. However, a significant modification is proposed for the portion of the program dealing with the pseudo-static earthquake analysis.

The existing program lowered factors of safety (FOS) for the effective stress analysis where excess, positive pore pressures were considered in the analysis. As mentioned on p. 14 of the User Manual (JHRP-75-9), (Ref. 10), the program considers the generation of excess pore pressures based on a seismic coefficient. These pressures are computed according to the inertial forces generated by the seismic coefficient (see p. 126, JHRP-77-25, Ref. 1). We feel that this is not particularly realistic, especially as it applies only to effective stress analysis. Conventionally, the selected seismic coefficient will be expected to account for such effects, as well as a loss of strength during an earthquake.

Thus, we have revised the program to include only the effects of additional inertial forces induced by the specified seismic coefficients, without changing the static pore pressures. For this revised method, the following changes are proposed:

1. Change the statement on line WGHT 704 to read:

   IF(RU(SOILTP).EQ.0..AND.CU(SOILTP).EQ.0.)GO TO 23

2. LINES WGHT 708, 710, 712 should be deleted.

Also note that a value for the cavitation pressure is required when using the EQUAKE option (see p. 41 in User Manual, Ref. 10). However, the following errata should be inserted in the User Manual to replace the second paragraph on p. 14:

> The inertial forces due to the seismic coefficients are at the center of gravity of each slice. These forces do not change the pre-earthquake static pore pressures in the slope. If significant excess pore pressures changes or loss of shear strength is expected, or in the case of a "high-risk" slope, a complete dynamic analysis should be performed.

There are other minor changes which do not affect the FOS computations. These are listed below:

1. In subroutine PROFIL:

   Line PROF1151 should read: CALL READER(DUMMY,NP(K),0)
   (date of change, 4-9-84)

2. In subroutine RANDOM:

   Line RAND1130 should read: WRITE(6,110)ERROR(20)
   (date of change, 4-9-84)

   after line RAND1830, insert these 3 lines:

```
     IF(MB .NE. 1) WRITE(6,136)
136  FORMAT(10X,' * * SAFETY FACTORS ARE CALCULTED BY THE ',
    1   'MODIFIED JANBU METHOD * *',//)
```

   (date of change, 1-9-84)

3. In subroutine RANSUF:

   Line RANS 766 should read: IF(ILIMIT.EQ.0) GO TO 2

   Line RANS 798 should read: GO TO 8

   After line RANS1376, insert: IF(SURF(K,1).LT.BPT)GO TO 3

   After line RANS1464, insert: IF(SURF(K,1).LT.BPT)GO TO 3
   (date of change, 3-1-83)

4. In subroutine FACTR:

   After line FCTR 492, insert: IF(A1(I).LT.0.0)A1(I)=0.0
   (date of change, 3-1-83)

5. For those Users with random generator subroutine RANF,

   Line RANF 4 should read: DATA XN,SEED/131072,27487/

   After line RANF 8, insert: IF(SEED.LT.0)SEED=SEED+XN
   (date of change, 3-1-83)

NOTE: All of the above are FORTRAN statements and should be inserted according to conventional programming rules into their correct column fields.

APPENDIX F

INPUT OF TIEBACK LOADS

F.1 Introduction

The use of tiebacks in geotechnical enginering and construction for stability of slopes and support of excavations has increased substantially within the last several years. As a result, the need for a method of analyzing the overall stability of slopes and retaining walls subjected to horizontal or inclined concentrated loads has become more evident. Until now, the input of horizontal or inclined concentrated loads acting on a near vertical slope was somewhat difficult in STABL. In addition the factor of safety was not formulated for this type of loading and thus, did not fully account for the distribution of force to the failure surface caused by concentrated boundary loads.

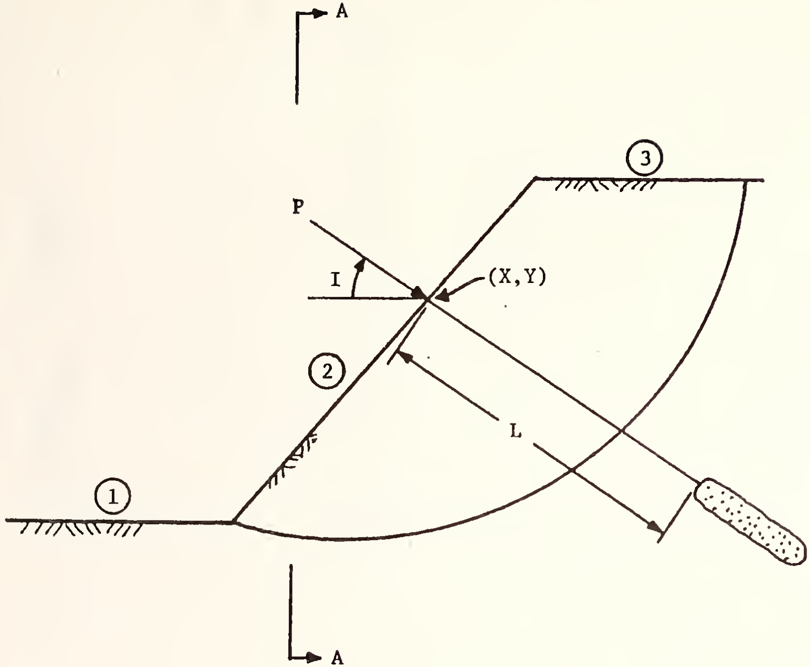
Therefore, to increase the versatility of STABL, new routines have been created within STABL to permit input of horizontal or inclined concentrated loads. These routines were created specifically for the input of tieback loads but may be easily used for any type of concentrated load applied to the ground surface. The latest version of STABL, STABL4, contains the new routines which utilize Flamant's Formulas as proposed by Morlier and Tenier (1982) and the modified Bishop method of analysis for circular failure surfaces, and the simplified Janbu method of analysis for non-circular failure surfaces. The tieback option may be used with either random or specific failure surface generation methods for irregular, block or circular failure surfaces. Throughout this appendix and within STABL4 the word "tieback" is used to mean tieback or other types of concentrated loads applied to the ground surface.

Tieback or other types of concentrated loads are input by specifying the ground surface boundary number where the load is to be applied, the Y coordinate of the point of application on the ground surface, the magnitude of the point load, the horizontal spacing between point loads, the inclination of the load as measured clockwise from the horizontal axis, and the length of the tieback, Figure F1. For concentrated boundary loads such as strut loads in a braced excavation which do not extend into the ground like tiebacks, the length of the tieback is zero. An equivalent line load is calculated for each tieback load specified assuming a uniform distribution of load horizontally between point loads.

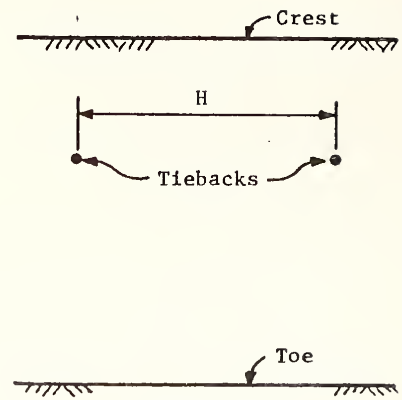
A short description of the new tieback routines is presented to help the User understand the method and assumptions used in STABL4 for analyzing slopes subjected to concentrated loads. Two example problems are also presented to demonstrate the input of horizontal and inclined loads and the effect of concentrated loads on the factor of safety against slope failure. The example problems include input and output data and plots. In addition, the input format for concentrated loads is presented along with input restrictions, error codes, and a listing of the additions and modificatons to STABL3 required to update that version to STABL4.

F.2 Description of New Tieback Routines

Unlike other slope stability programs, STABL4 distributes the force from a concentrated load throughout the soil mass to the whole failure



Elevation



Section A-A

Tieback Input Parameters

2	Ground surface boundary number where tieback load is applied
Y	Y coordinate of point of application (ft) or (m)
P	Magnitude of load per tieback (lbs) or (kg)
H	Horizontal spacing between tiebacks (ft) or (m)
I	Inclination of tieback load (deg)
L	Free length of tieback (ft) or (m)

FIGURE F1 - TIEBACK INPUT PARAMETERS

surface and hence to all slices of the sliding mass. Other slope stability programs on the other hand, only take a concentrated load into account on the slice on which it acts. This distribution of load throughout the soil mass is a unique feature of STABL4.

First an equivalent line load is calculated for a row of tiebacks by dividing the specified tieback load (point load) by the corresponding horizontal spacing between tieback loads. The resulting line load is called TLOAD, Figure F2, and is inclined from the horizontal by an angle INCLIN. The radial stress on the midpoint of a slice is calculated using Flamant's Formula (Morlier and Tenier, 1982):

$$\sigma_r = \frac{2(\mathrm{TLOAD})\cos(\mathrm{TTHETA})}{(\pi)(\mathrm{DIST})}$$

where

σ_r = Radial stress

TLOAD = Equivalent tieback line load

TTHETA = Angle between the line of action of the tieback and the line between the point of application of the tieback on the ground surface and the midpoint of a slice.

π = pi

DIST = Distance between the point of application of the tieback on the ground surface and the midpoint of a slice.

The radial force, PRAD, at the midpoint of the base of the slice due to the concentrated load is calculated by multiplying the radial stress by the length of the base of the slice:

$$\mathrm{PRAD} = \frac{2(\mathrm{TLOAD})\cos(\mathrm{TTHETA})}{(\pi)(\mathrm{DIST})} \cdot \frac{(\mathrm{DX})}{\cos(\mathrm{ALPHA})}$$

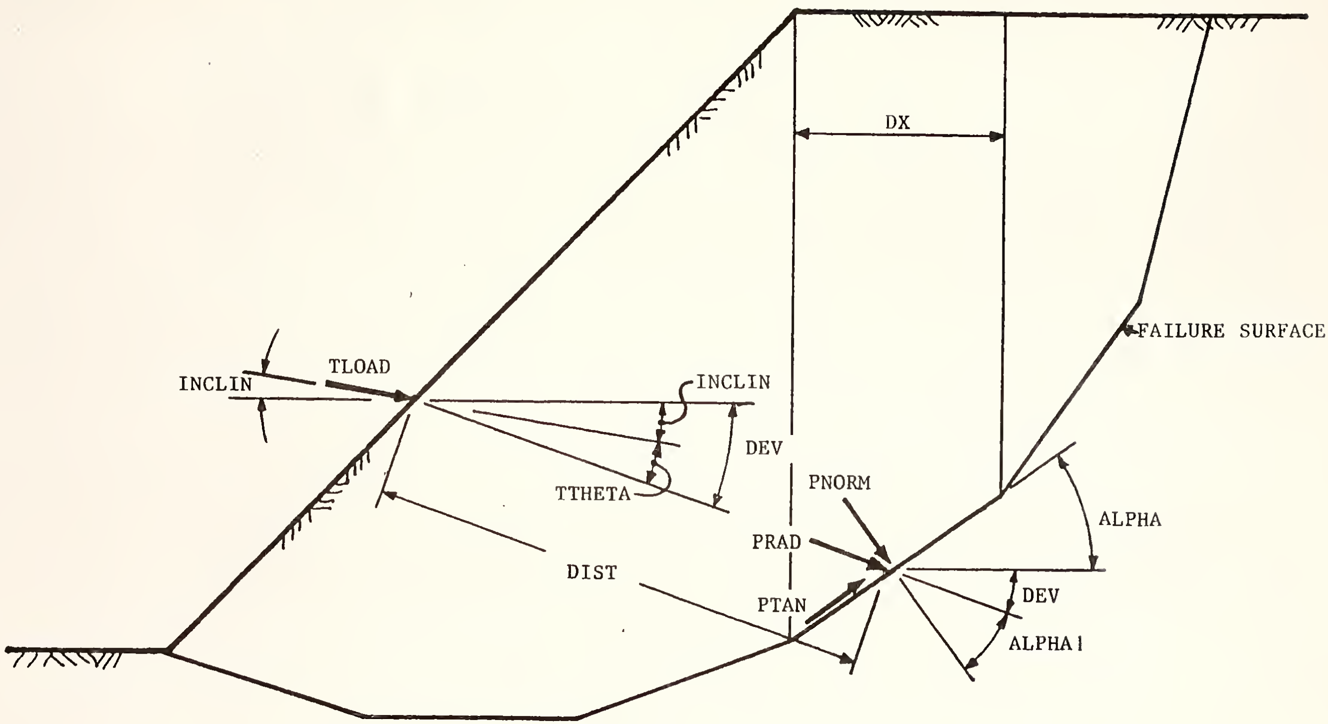


FIGURE F2 - TRANSFER OF CONCENTRATED LOAD TO FAILURE SURFACE

where

PRAD	=	Radial force on base of slice due to concentrated load
ALPHA	=	Inclination of base of slice
DX	=	Slice width

Note that the radial stress produced on the base of the slice by the concentrated load is proportional to the load applied (TLOAD) and the width of the slice (DX), inversely proportional to the distance between the point of application of the load and the midpoint of the base of the slice (DIST), and dependent upon the angle between the line of action of the load and the line between the point of application of the load and the midpoint of the base of the slice (TTHETA). Therefore, slices which are in line with the direction of the concentrated load will receive a larger portion of the total load than will slices which are farther away and whose angle TTHETA is large.

The radial force PRAD is distributed in the same manner to all the slices of the sliding mass. The radial forces on all the slices are then summed in the direction of the concentrated load, PSUM, and compared with the applied load, TLOAD. Since the sum of radial forces for a failure surface, PSUM, is not always exactly equal to the applied load due to slope geometry and the shape of the failure surface, the radial force applied to the base of each slice is modified as follows:

$$\text{PRAD} = \text{TLOAD}/\text{PSUM}$$

The refined radial force for each slice, PRAD, is broken into its components normal and tangential to the base of the slice for calcula-

tion of the factor of safety. The normal and tangential components of the force due to the concentrated load are respectively:

$$PNORM = (PRAD)\cos(ALPHA1)$$

$$PTAN = (PRAD)\sin(ALPHA1)$$

The same process is repeated for all additional rows of tiebacks. The sum of the normal components and the sum of the tangential components due to all rows of tiebacks are then used in the slice equilibrium equations for calculating the factor of safety.

There is a special case where the tieback loads will not be distributed to quite all the slices of the sliding mass and is shown in Figure F3. Figure F3 shows the limit of the stress distribution for a benched slope. The force due to the applied load is not distributed to the slices of the far left or the slices of the far right since this would require distribution of load through air and not the soil mass.

Examples showing the use of the new tieback routines in STABL4 are presented in the next section.

F.3 Examples Using Concentrated Loads

The details of the examples presented are not of concern since the primary purpose of the examples is to demonstrate the use of the new routines for concentrated loads. It should be noted that the critical failure surface and the minimum factor of safety will change in most instances due to the introduction of concentrated horizontal or inclined loads. In addition, the examples presented herein only analyze a specified failure surface for the sake of simplicity and clarity. A random

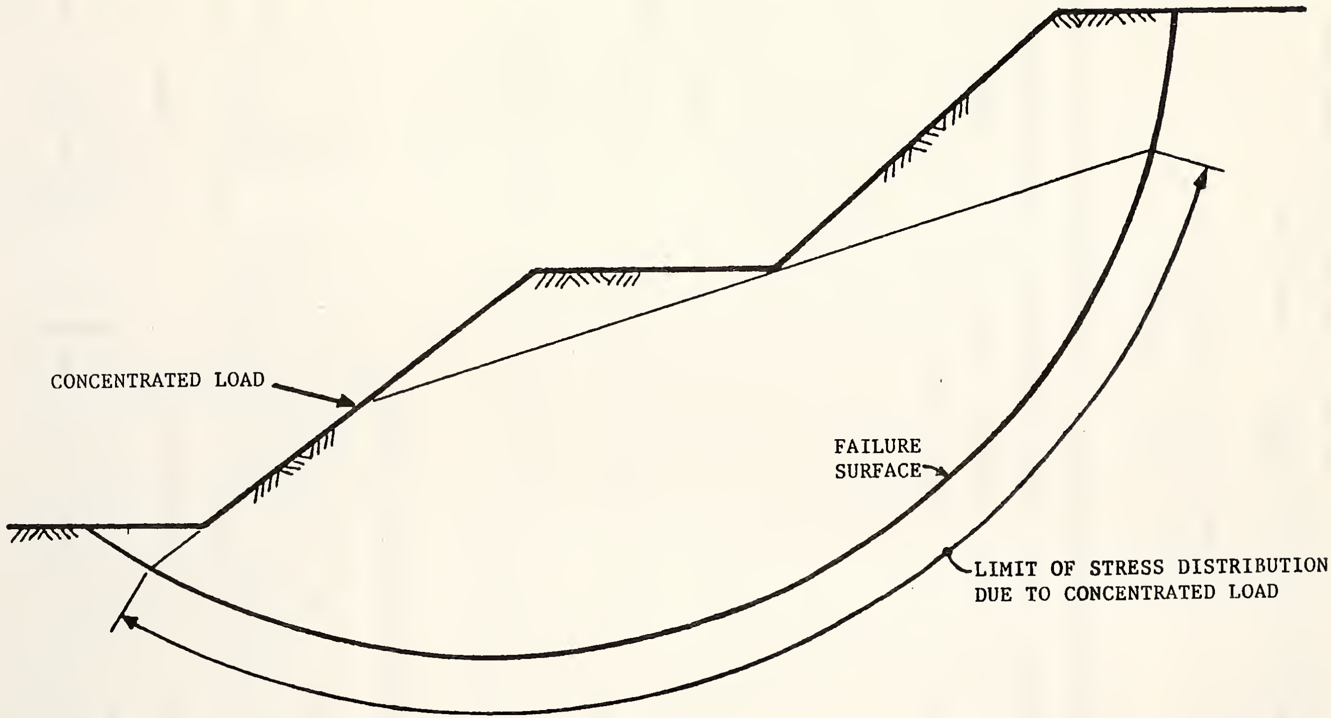


FIGURE F3 - LIMIT OF STRESS DISTRIBUTION DUE TO CONCENTRATED LOAD

search should always be performed to find the new critical failure surface and corresponding minimum factor of safety against overall slope failure.

The profile shown in Figure F4 represents a proposed excavation in a silty sand with vertical sides supported by steel sheet piling. It has been determined that the critical failure surface is circular and exits the slope at the toe of the sheeting. The minimum factor of safety for overall stability was determined to be 0.451 for the critical surface with center at (41 ft, 76 ft) (12.50 m, 23.16 m) and radius 41.9 ft (12.77 m).

Two methods of support have been proposed. The first method involves using two rows of tiebacks and the second method involves using a bracing system inside the excavation.

F.3.1 Example Problem #1

It has been determined that two rows of tiebacks are required for local stability of the wall (Figure F5). The first (upper) row of tiebacks will be horizontal and the free length of the tiebacks will be 40 ft (12.19 m). The first row of tiebacks will each carry a load of 150,000 lbs (68,040 kg) and will be spaced 10 ft (3.05 m) apart horizontally. The second (lower) row of tiebacks will be inclined 15 degrees as measured clockwise from the horizontal and will have a free length of 30 ft (9.14 m). Each tieback in this row will carry a load of 200,000 lbs (90,720 kg) and will also be at a 10 ft (3.05 m) horizontal spacing. Both rows of tiebacks will transfer their loads to the sheeting using horizontal steel beams for wales. Therefore, the assumption of a

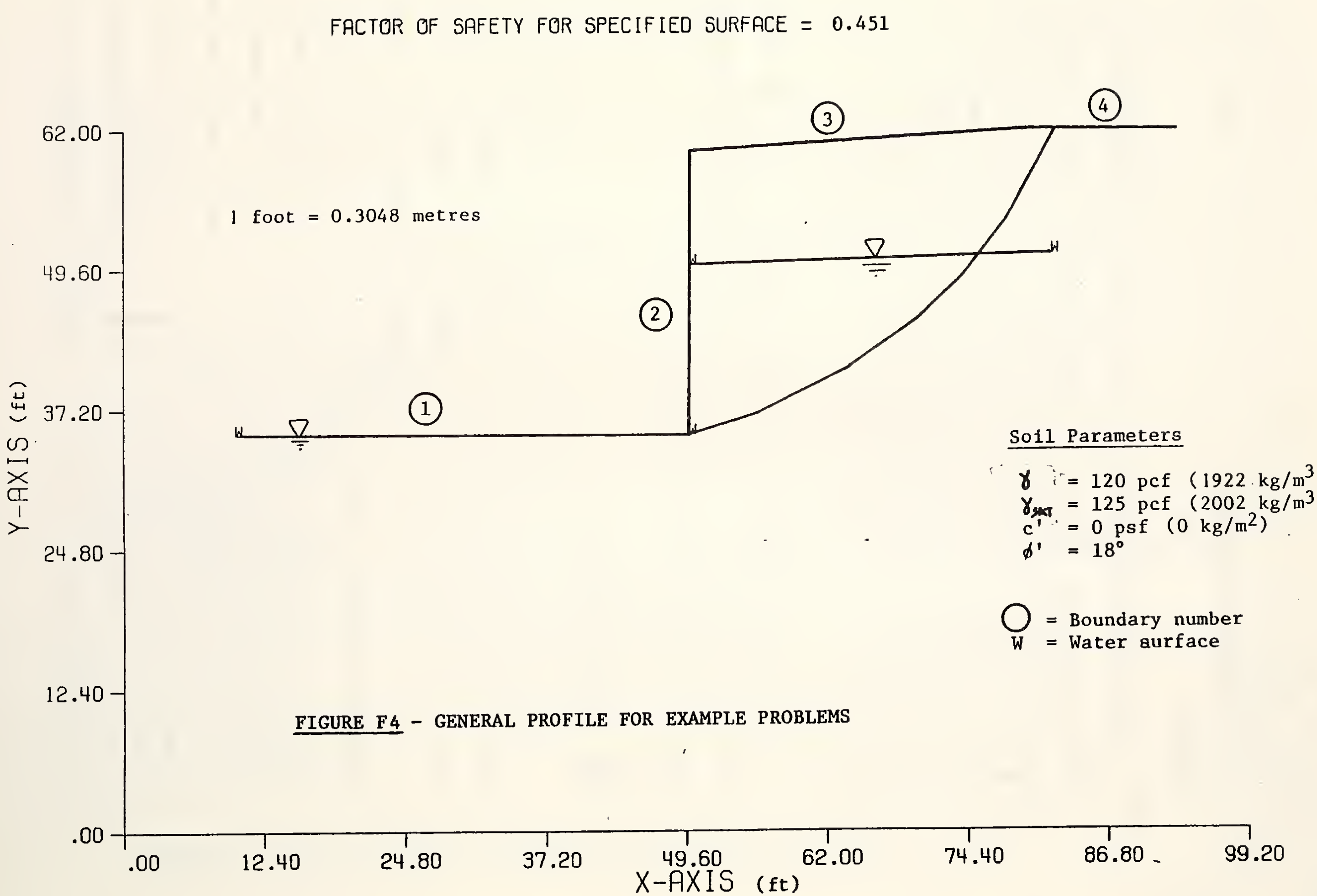


FIGURE F4 - GENERAL PROFILE FOR EXAMPLE PROBLEMS

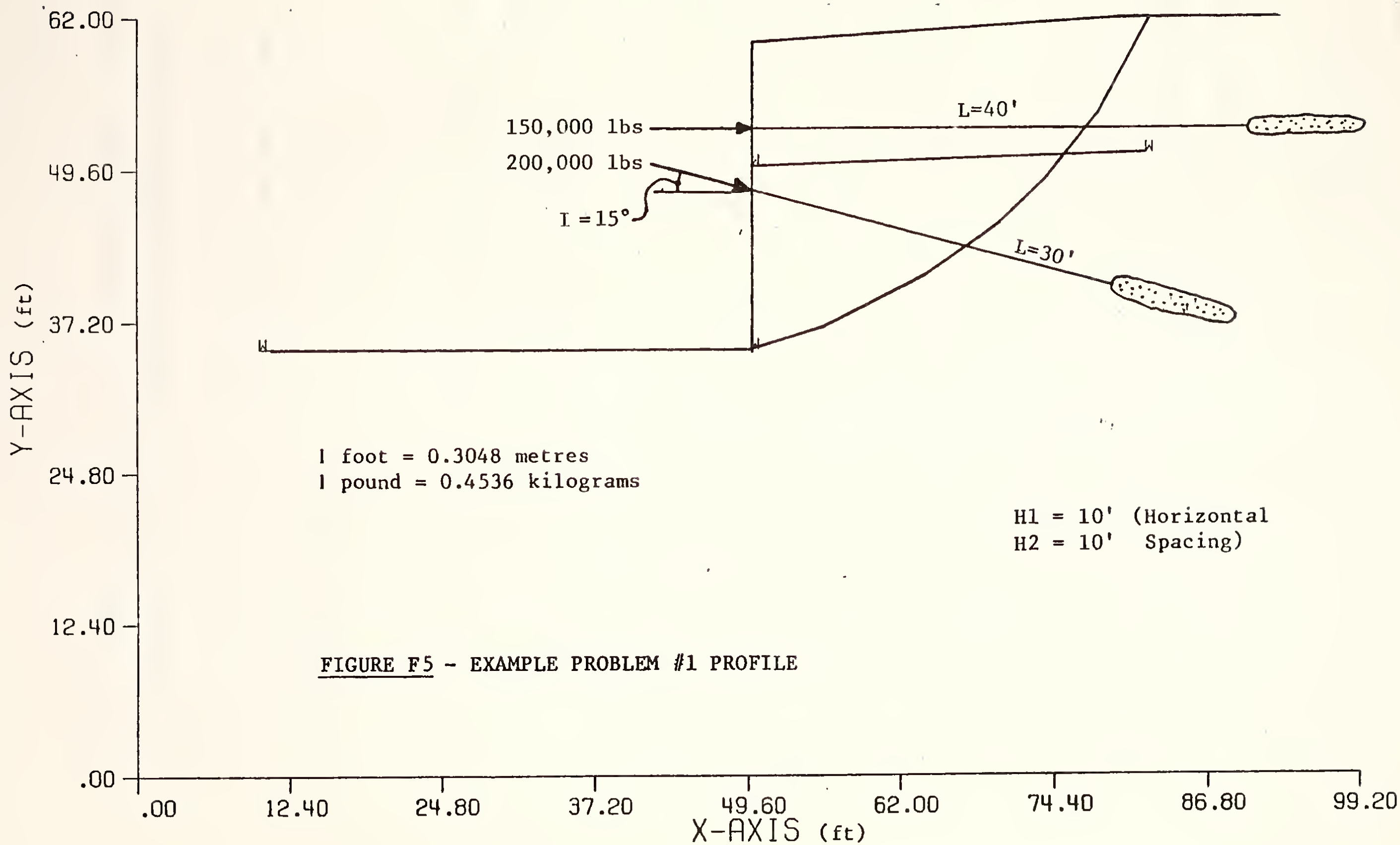


FIGURE F5 - EXAMPLE PROBLEM #1 PROFILE

uniform distribution of load between the tiebacks will be reasonable for this case since the action of the wale will cause an equivalent horizontal line load to be formed for each row of tiebacks.

It is desired to know what effect the tiebacks have on the factor of safety of the previously mentioned critical failure surface. Therefore, the program will be run using a specified circular failure surface and the input data shown in Figure F6. The output for this run is given in Figures F7, F8 and F9.

Note that if the unbonded portion of any tieback does not intersect the failue surface, i.e., terminates within the sliding mass as in tiebacks #1 and #2 of Figure F10, the load from that particular row of tiebacks will not be considered in the factor of safety calculation. Only the load from tieback #3 of Figure F10 would be considered in the factor of safety calculation since the failure surface intersects the unbonded portion of tieback #3.

As will be seen in the next example, the length of a "tieback" for a braced system of support is equal to zero and all concentrated loads will be considered for all failure surfaces in the factor of safety calculation.

F.3.2 Example Problem #2

The second method of support proposed involves using bracing to provide local and overall stability to the wall (Figure F11). The bracing system will consist of horizontal struts bearing against steel wales which transfer their loads to the sheet piling. The first level of

```
PROFIL
TIEBACK EXAMPLE PROBLEM #1
4 4
10. 35. 50. 35. 1
50. 35. 50.1 60. 1
50.1 60. 80. 62. 1
80. 62. 93. 62. 1
SOIL
1
120. 125. 0. 18. 0. 0. 1
WATER
1 62.4
4
10. 35.
50. 35.
50.01 50.
82. 51.
TIES
2
2 53. 150000. 10. 0. 40.
2 48. 200000. 10. 15. 30.
SURBIS
7
50. 35.2
56. 36.8
64. 40.9
70. 45.1
74. 49.
78. 54.1
82.3 62.
EXECUT
```

FIGURE F6 - INPUT DATA FOR EXAMPLE #1

--SLOPE STABILITY ANALYSIS--
SIMPLIFIED JANBU METHOD OF SLICES
OR SIMPLIFIED BISHOP METHOD

PROBLEM DESCRIPTION TIEBACK EXAMPLE PROBLEM #1

BOUNDARY COORDINATES

4 TOP BOUNDARIES
4 TOTAL BOUNDARIES

BOUNDARY NO.	X-LEFT (FT)	Y-LEFT (FT)	X-RIGHT (FT)	Y-RIGHT (FT)	SOIL TYPE BELOW BND
1	10.00	35.00	50.00	35.00	1
2	50.00	35.00	50.10	60.00	1
3	50.10	60.00	80.00	62.00	1
4	80.00	62.00	93.00	62.00	1

ISOTROPIC SOIL PARAMETERS

1 TYPE(S) OF SOIL

SOIL TYPE NO.	TOTAL UNIT WT. (PCF)	SATURATED UNIT WT. (PCF)	COHESION INTERCEPT (PSF)	FRICTION ANGLE (DEG)	PORE PRESSURE PARAMETER	PRESSURE CONSTANT (PSF)	PIEZOMETRIC SURFACE NO.
1	120.0	125.0	0	18.0	0	0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

UNIT WEIGHT OF WATER = 62.40

PIEZOMETRIC SURFACE NO. 1 SPECIFIED BY 4 COORDINATE POINTS

POINT NO.	X-WATER (FT)	Y-WATER (FT)
1	10.00	35.00
2	50.00	35.00
3	50.01	50.00
4	82.00	51.00

TIEBACK LOAD(S)

2 TIEBACK LOAD(S) SPECIFIED

TIEBACK NO.	X-POS (FT)	Y-POS (FT)	LOAD (LBS)	SPACING (FT)	INCLINATION (DEG)	LENGTH (FT)
1	50.07	53.00	150000.0	10.0	0	40.0
2	50.05	48.00	200000.0	10.0	15.00	30.0

FIGURE F7 - OUTPUT FOR EXAMPLE #1

TRIAL FAILURE SURFACE SPECIFIED BY 7 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	50.00	35.00
2	56.00	36.80
3	64.00	40.90
4	70.00	45.10
5	74.00	49.00
6	78.00	54.10
7	82.30	62.00

CIRCLE CENTER AT X = 41.0 ; Y = 76.0 AND RADIUS, 41.9

FACTOR OF SAFETY FOR THE PRECEDING SPECIFIED SURFACE = 1.870

WARNING - FACTOR OF SAFETY IS CALCULATED BY THE MODIFIED BISHOP METHOD. THIS METHOD IS VALID ONLY IF THE FAILURE SURFACE APPROXIMATES A CIRCLE.

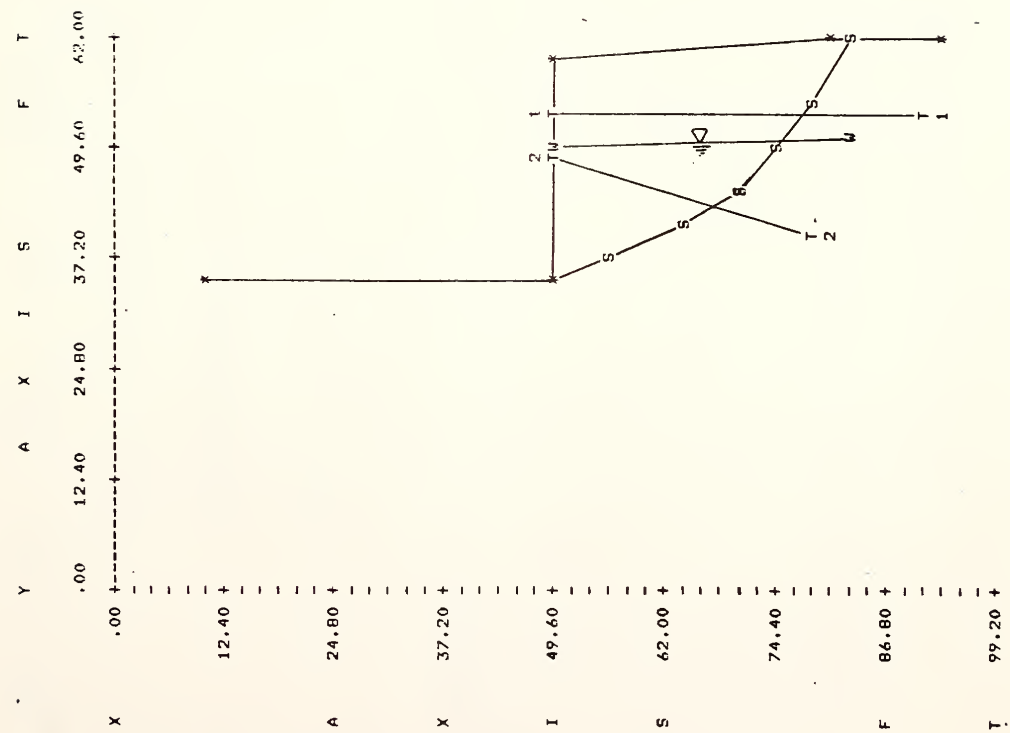


FIGURE F8 - OUTPUT FOR EXAMPLE #1 (Continued)

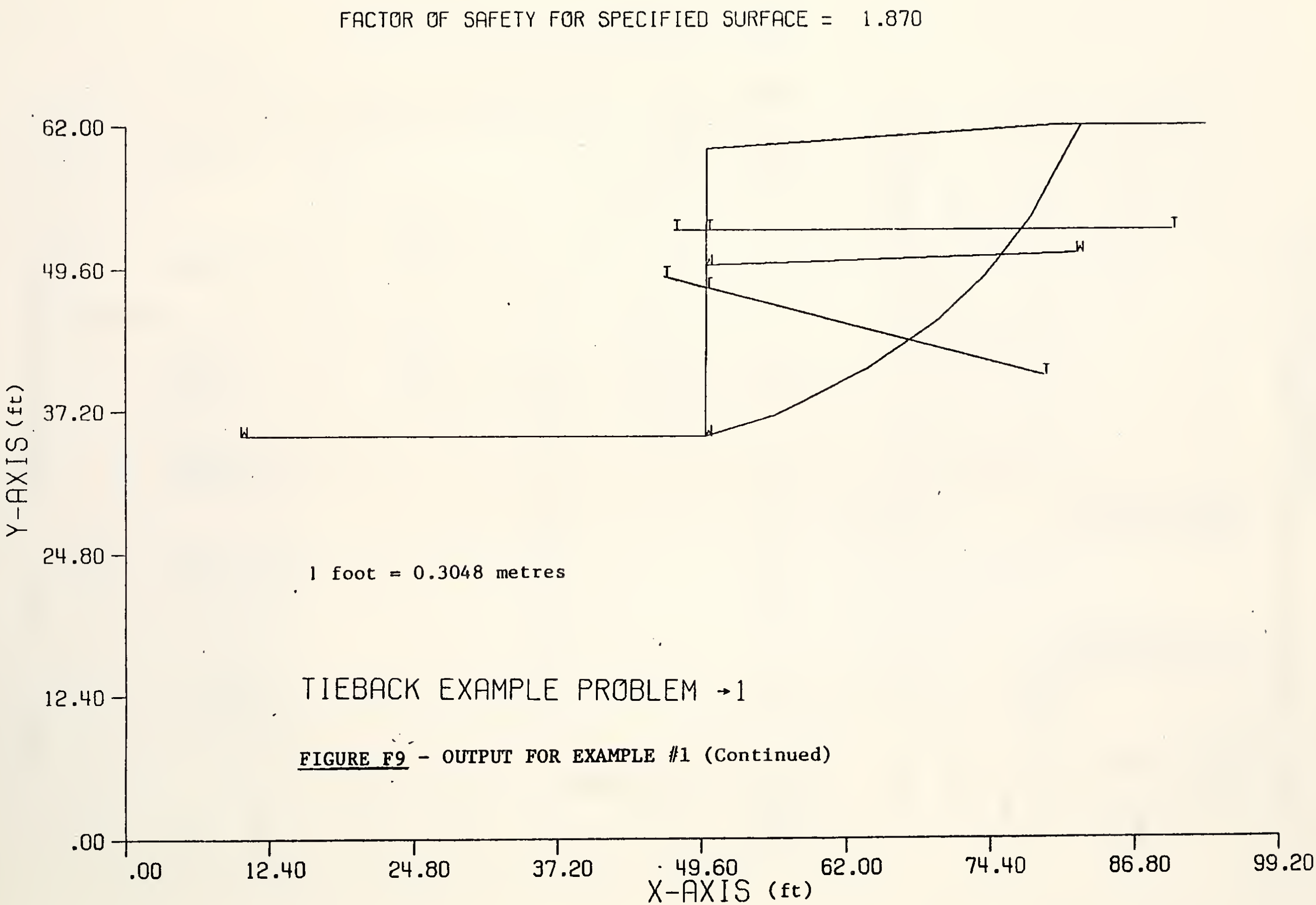


FIGURE F9 - OUTPUT FOR EXAMPLE #1 (Continued)

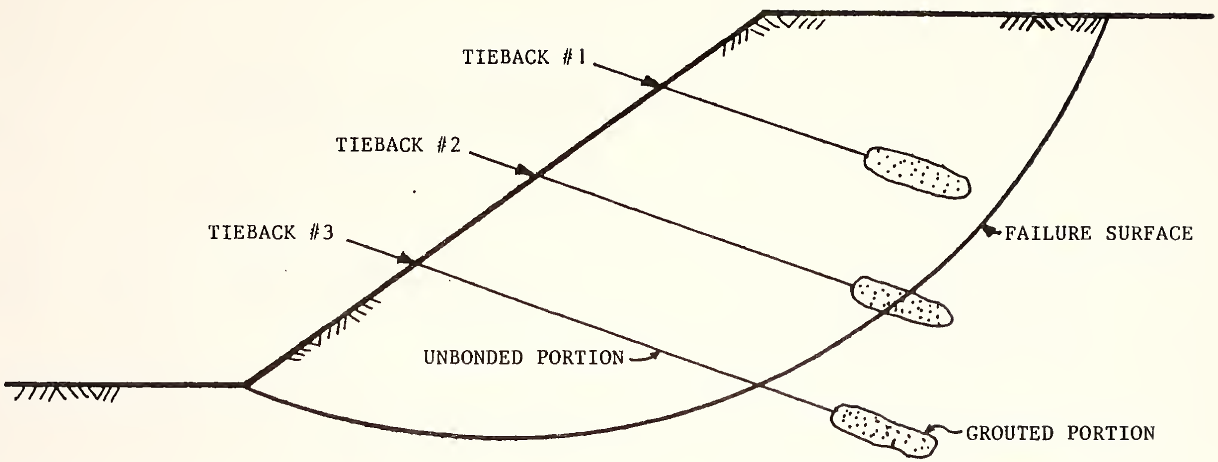


FIGURE 10 - INTERSECTION OF TIEBACK WITH FAILURE SURFACE

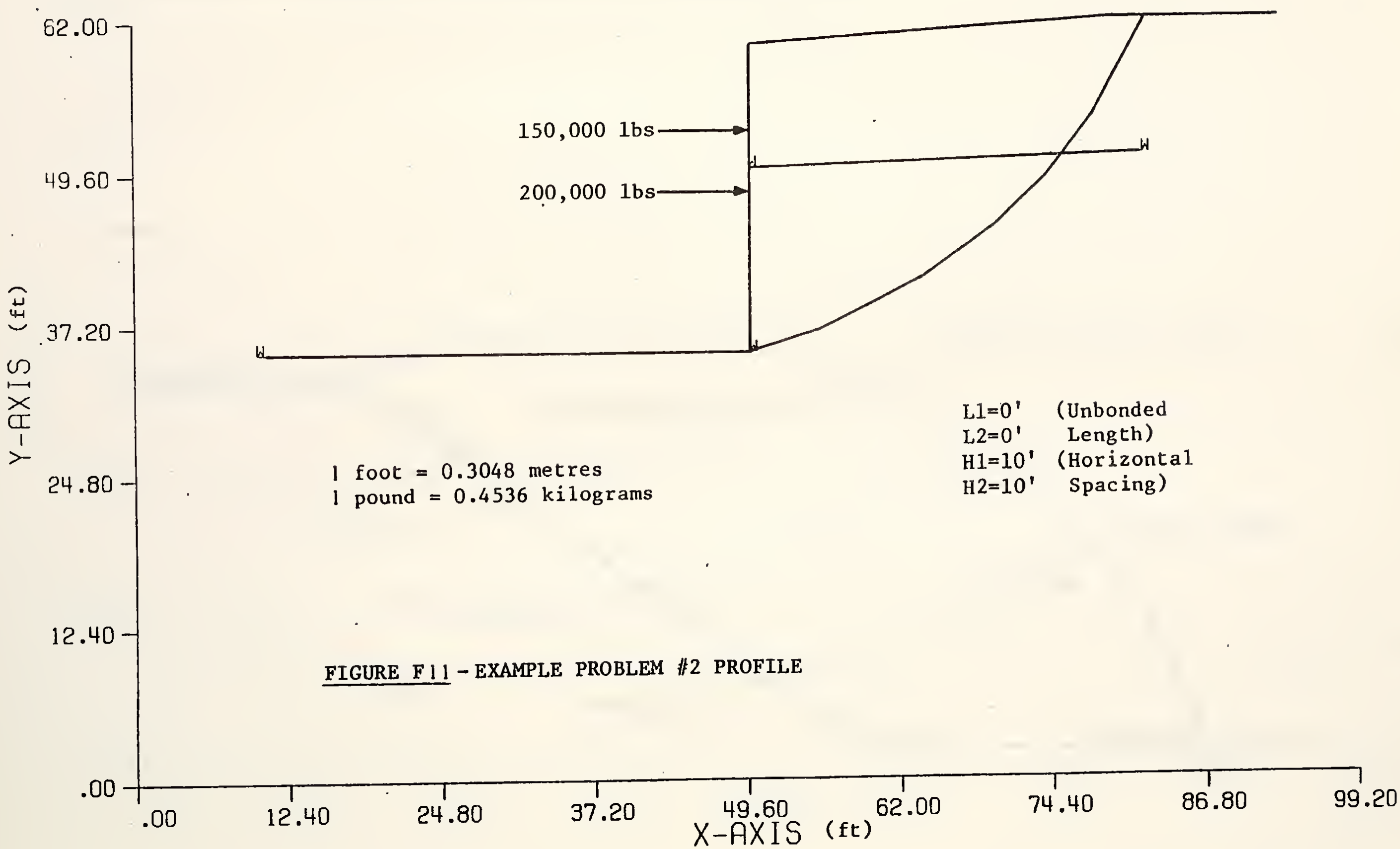


FIGURE F11 - EXAMPLE PROBLEM #2 PROFILE

struts will carry 150,000 lbs/strut (68,040 kg/strut) and will be spaced 10 ft (3.05 m) apart. The second level of struts will carry 200,000 lbs/strut (90,720 kg/strut) and will be spaced 10 ft (3.05 m) apart. Again the assumption of a uniform distribution load between the struts is reasonable due to wale action.

Again the program is run using the input data shown in Figure F12 for the braced excavation and a specified failure surface and the output is given in Figures F13, F14 and F15. As mentioned in Example #1, the length of a "tieback" for a concentrated load such as the load produced by a row of struts is input as zero. All concentrated loads with length zero will be used for the calculation of the factor of safety for all failure surfaces.

F.4.1 Data Input Format for Tieback Loads (if specified)

COMMAND CARD	TIES	Command Code
DATA CARD	Integer	Number of tieback loads
DATA CARD	Integer	Boundary number where tieback load is applied
	Real	Y coordinate of the point of application of tieback load (ft) or (m)
	Real	Load per tieback (lbs) or (kg)
	Real	Horizontal spacing between tiebacks (ft) or (m)
	Real	Inclination of tieback load as measured clockwise from the horizontal plane (deg)
	Real	Free length of tieback (ft) or (m) (Equal to zero if other than a tieback load)

Note: Repeat preceding data card for each tieback load.

```
PROFIL
TIEBACK EXAMPLE PROBLEM #2
4 4
10. 35. 50. 35. 1
50. 35. 50.1 60. 1
50.1 60. 80. 62. 1
80. 62. 93. 62. 1
SOIL
1
120. 125. 0. 18. 0. 0. 1
WATER
1 62.4
4
10. 35.
50. 35.
50.01 50.
82. 51.
TIES
2
2 53. 150000. 10. 0. 0.
2 48. 200000. 10. 0. 0.
SURBIS
7
50. 35.2
56. 36.8
64. 40.9
70. 45.1
74. 49.
78. 54.1
82.3 62.
EXECUT
```

FIGURE F12 - INPUT DATA FOR EXAMPLE #2

--SLOPE STABILITY ANALYSIS--
SIMPLIFIED JANBU METHOD OF SLICES
OR SIMPLIFIED BISHOP METHOD

PROBLEM DESCRIPTION   TIEBACK EXAMPLE PROBLEM #2

BOUNDARY COORDINATES

4 TOP BOUNDARIES
4 TOTAL BOUNDARIES

BOUNDARY NO.	X-LEFT (FT)	Y-LEFT (FT)	X-RIGHT (FT)	Y-RIGHT (FT)	SOIL TYPE BELOW BND
1	10.00	35.00	50.00	35.00	1
2	50.00	35.00	50.10	60.00	1
3	50.10	60.00	80.00	62.00	1
4	80.00	62.00	93.00	62.00	1

ISOTROPIC SOIL PARAMETERS

1 TYPE(S) OF SOIL

SOIL TYPE NO.	TOTAL UNIT WT. (PCF)	SATURATED UNIT WT. (PCF)	COHESION INTERCEPT (PSF)	FRICTION ANGLE (DEG)	PORE PRESSURE PARAMETER	PRESSURE CONSTANT (PSF)	PIEZOMETRIC SURFACE NO.
1	120.0	125.0	0	18.0	0	0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

UNIT WEIGHT OF WATER = 62.40

PIEZOMETRIC SURFACE NO. 1 SPECIFIED BY 4 COORDINATE POINTS

POINT NO.	X-WATER (FT)	Y-WATER (FT)
1	10.00	35.00
2	50.00	35.00
3	50.01	50.00
4	82.00	51.00

TIEBACK LOAD(S)

2 TIEBACK LOAD(S) SPECIFIED

TIEBACK NO.	X-POS (FT)	Y-POS (FT)	LOAD (LBS)	SPACING (FT)	INCLINATION (DEG)	LENGTH (FT)
1	50.07	53.00	150000.0	10.0	0	0
2	50.05	48.00	200000.0	10.0	0	0

FIGURE F13 - OUTPUT FOR EXAMPLE #2

TRIAL FAILURE SURFACE SPECIFIED BY 7 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	50.00	35.00
2	56.00	36.80
3	64.00	40.90
4	70.00	45.10
5	74.00	49.00
6	78.00	54.10
7	82.30	62.00

CIRCLE CENTER AT X = 41.0 ; Y = 76.0 AND RADIUS, 41.9

FACTOR OF SAFETY FOR THE PRECEDING SPECIFIED SURFACE = 2.071

WARNING - FACTOR OF SAFETY IS CALCULATED BY THE MODIFIED BISHOP
METHOD. THIS METHOD IS VALID ONLY IF THE FAILURE SURFACE
APPROXIMATES A CIRCLE.

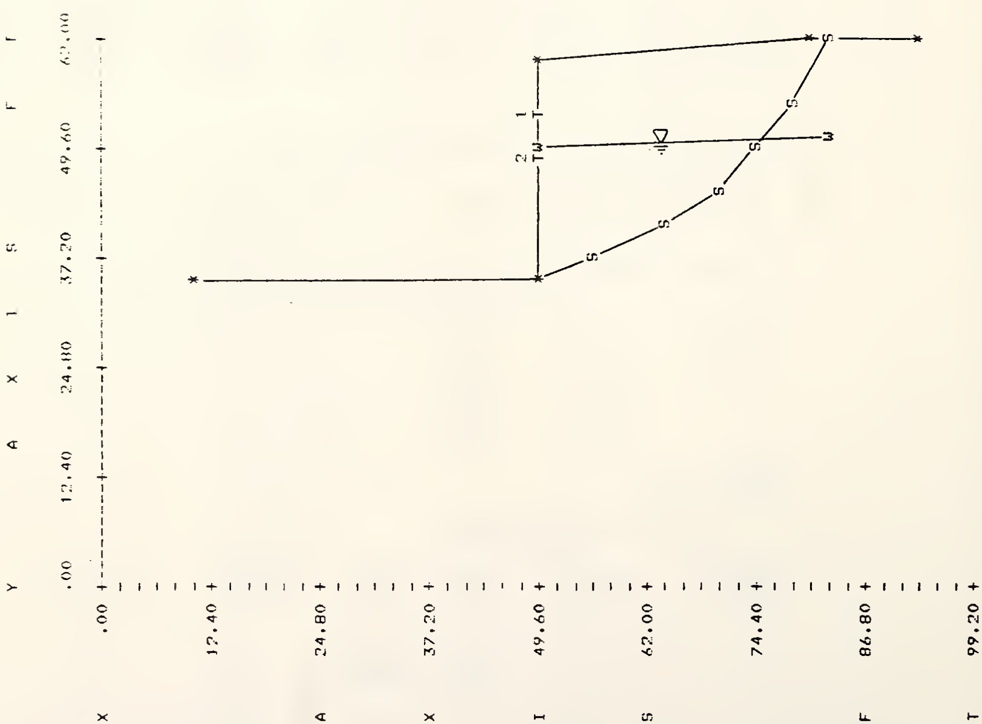


FIGURE F14 - OUTPUT FOR EXAMPLE #2 (Continued)

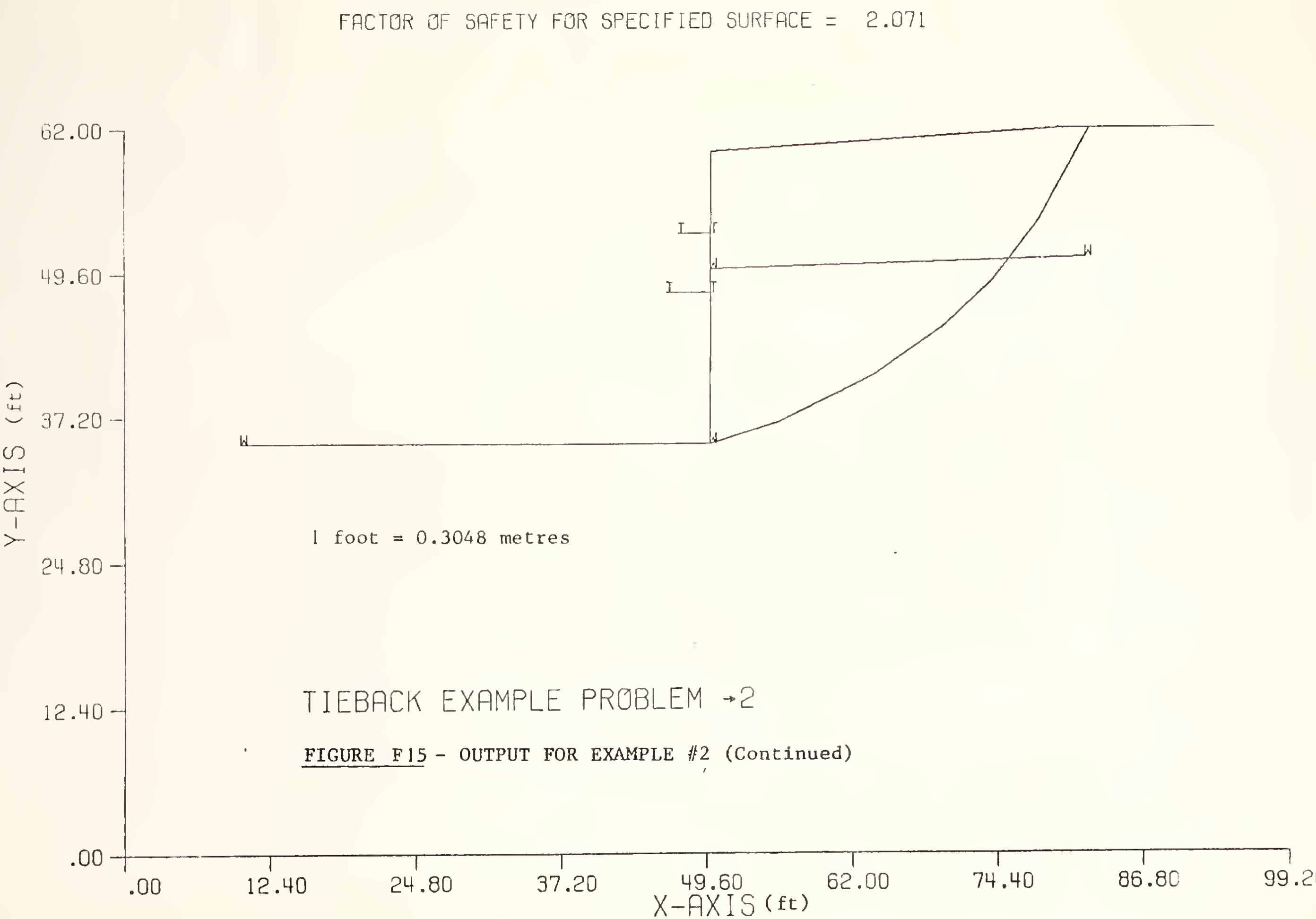


FIGURE F15 - OUTPUT FOR EXAMPLE #2 (Continued)

F.4.2 Input for Suppressing or Reactivating Tieback Loads (if specified)

COMMAND CARD	TIES	Command Code
DATA CARD	Integer	Number zero (0)

F.5 Input Restrictions

1. The point of application of a tieback on the ground surface may not be at a ground surface boundary node. Use a slight vertical offset, (i.e. 70.01 instead of 70).

2. No more than 10 tieback loads can be specified but they can be in any order.

3. The inclination of a tieback must be equal to or greater than zero degrees and less than 90 degrees as measured clockwise from the horizontal.

4. The horizontal spacing between tiebacks must be greater than or equal to 1 ft (or 1 metre if using SI units).

5. The length of a tieback must be equal to or greater than zero ft. Zero is used for loads other than tieback type of loads.

F.6 TIES Error Codes

TI01 - An attempt has been made to suppress or reactivate undefined tieback loads. Data must be defined by a prior use of command TIES before they can be suppressed. Suppressed data can not be reactivated if command PROFIL has been used in the

execution sequence subsequent to their use, whether the data are active or suppressed.

TI02 - The number of tieback loads specified exceeds 10. The problem must either be redefind so fewer tieback loads are used, or dimensioning of the program must be increased to accomodate the problem as defined.

TI03 - A negative coordinate has been specified for the tieback load indicated or the calculated Y coordinate of the end of the tieback is negative. All problem geometry must be located within the 1st quadrant.

TI04 - The inclination limits have been exceeded for the tieback load indicated. The inclination of a tieback load must be equal to or greater than zero (deg) and less than 90 (deg) as measured clockwise from the horizontal.

TI05 - The point of application of the tieback load specified does not lie on the ground surface boundary specified. Check the boundary number specified and the Y coordinate of the point of application of the tieback load indicated.

TI06 - The horizontal spacing between tiebacks for the row of tiebacks indicated is incorrect. The horizontal spacing between tiebacks must be greater than or equal to 1 ft (or 1 metre if using SI units).

TI07 - The length of the tieback indicated is incorrect. The length of a tieback must be greater than or equal to zero (ft). Zero is used for loads other than tieback type of loads.

F.7 List of Program Additions and Modifications

The following pages list the program lines which have been modified and new lines which are required for calculation of the factor of safety considering the presence of concentrated loads. There are two new subroutines, TIES and TRANS. Program lines which have been modified for the input of concentrated loads are denoted by JRCMAR84 which indicates that they were modified by James R. Carpenter, March 1984.

The last two pages of this section list the lines which must be interchanged in and/or added to STABL4 to run the program on an IBM computer.

CHANGES FOR PROGRAM STABL3:

```
C     ------------------------------------------------------------------STBL    4
C     ------------------------------------------------------------------STBL    6
C                              PROGRAM STABL4                            JRCMAR84
C     ------------------------------------------------------------------STBL   10
C     ------------------------------------------------------------------STBL   12
C                                                                        STBL   14
C     AUTHOR -                                                           STBL   16
C                                                                        STBL   18
C          RONALD A. SIEGEL, GRADUATE RESEARCH ASSISTANT,  1975.         STBL   20
C                                                                        STBL   22
C     REVISED BY -                                                       OCT76EBO
C                                                                        OCT76EBO
C          EVA BOUTRUP, GRADUATE RESEARCH ASSISTANT,  JANUARY 1978.      JAN78EBO
C                                                                        OCT76EBO
C     REVISED BY -                                                       MGOODMAN
C                                                                        JRCMAR84
C          MARTIN GOODMAN, GRADUATE RESEARCH ASSISTANT, AUGUST 1982.     MGOODMAN
C                                                                        MGOODMAN
C     REVISED BY -                                                       JRCMAR84
C                                                                        JRCMAR84
C          JAMES R. CARPENTER, GRADUATE RESEARCH ASSISTANT, MARCH 1984.  JRCMAR84
C                                                                        JRCMAR84
C     SPONSOR -                                                          STBL   24
C                                                                        STBL   26


C                   OUT DATA DEFINING AN INDIVIDUAL TRIAL FAILURE        STBL  224
C                   SURFACE.                                             STBL  226
C                                                                        JRCMAR84
C          TIES     SUBROUTINE THAT READS IN, CHECKS, STORES, AND PRINTS JRCMAR84
C                   OUT TIEBACK ANCHOR LOAD DATA.                        JRCMAR84
C                                                                        STBL  228
C          TOL      TOLERANCE CONSTANT TO ACCOUNT FOR MACHINE ROUNDING.  STBL  230
```

```
C                                                                       STBL 244
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,   STBL 246
     1             IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL       JRCMAR84
      COMMON /BLK15/ M,MB                                               STBL 249
      DIMENSION KEYW(16),ERROR(5)                                       JRCMAR84
      DATA KEYW/6HPROFIL,5HLOADS,4HTIES,5HWATER,6HSURFAC,6HEXECUT,      JRCMAR84
     1   6HEQUAKE,4HSOIL,6HRANDOM,6HCIRCLE,6HCIRCL2,5HBLOCK,6HBLOCK2,   JRCMAR84
     1   6HLIMITS,5HANISO,6HSURBIS/                                     JRCMAR84
      DATA ERROR/4HSQ01,4HSQ02,4HSQ03,4HSQ04,4HSQ05/                    STBL 256
      TOL=.0001                                                         STBL 258

C   ---------------------------------------------                       STBL 354
C                                                                       STBL 356
   23 DO 12 I=1,16                                                      JRCMAR84
      IF(MKEYW.EQ.KEYW(I))GO TO (1,2,28,3,4,5,6,7,9,10,8,14,18,15,16,   JRCMAR84
     1   13),I                                                          JRCMAR84
   12 CONTINUE                                                          STBL 362
C                                                                       STBL 364

     1           10X,'******  ',A6,'  - ILLEGAL COMMAND  ******'/       STBL 380
     1           10X,'****************************************'/)       STBL 382
      WRITE(6,102)(KEYW(I),I=1,16)                                      JRCMAR84
  102 FORMAT(//,10X,'LEGAL COMMANDS - ',A6,/,(27X,A6))                  STBL 386
      CALL QUIT                                                         STBL 388

    2 CALL LOADS                                                        STBL 394
      GO TO 11                                                          STBL 396
   28 CALL TIES                                                         JRCMAR84
      GO TO 11                                                          JRCMAR84
    3 CALL WATER                                                        STBL 398
      GO TO 11                                                          STBL 400
```

CHANGES FOR SUBROUTINE READER:

```
C                                                                    READ 144
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,   READ 146
     1             IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL    JRCMAR84
      COMMON /BLK08/NSLICE,X(300)                                    READ 150
      DIMENSION M(80),N(14),A(10),IA(10),ERROR(7)                    READ 152
```

CHANGES FOR SUBROUTINE PROFIL:

```
C        ISURF     CONTROL CODE WHICH INDICATES DEFINITION OF SPECIFIED PROF 208
C                  TRIAL FAILURE SURFACE.                            PROF 210
C                                                                    JRCMAR84
C        ITIES     CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM JRCMAR84
C                  HANDLING THE TIEBACK ANCHOR LOADS SPECIFIED BY    JRCMAR84
C                  SUBROUTINE TIES.                                  JRCMAR84
C                                                                    PROF 212
C        ITP       ARRAY CONTAINING SOIL TYPE INDICES FOR EACH BOUNDARY.PROF 214

C        NSURC     NUMBER OF BOUNDARY LOADS SPECIFIED.               PROF 274
C                                                                    PROF 276
C        NTIES     NUMBER OF TIEBACK ANCHOR LOADS SPECIFIED.         JRCMAR84
C                                                                    JRCMAR84
C        NTOP      NUMBER OF GROUND SURFACE BOUNDARIES.              PROF 278
C                                                                    PROF 280

      DIMENSION TITLE(4), DESCR(4), ERROR(11)                        PROF 344
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,   PROF 346
     1             IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL    JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND, PROF 350
     1             NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)           PROF 352
```

```
     1                PHIA(10,10)                                   PROF 362
      COMMON /BLK11/CAVT,KCOEF,VKCOEF                               PROF 364
      COMMON /BLK16/NTIES,INCLIN(10),PLOAD(10),SPACE(10),TLOAD(10), JRCMAR84
     1                XTIE(10),YTIE(10),BN(10),LENGTH(10),XEND(10), JRCMAR84
     1                YEND(10)                                      JRCMAR84
      DATA ERROR/4HPF01,4HPF02,4HPF03,4HPF04,4HPF05,4HPF06,4HSL01,  PROF 366
     1   4HSL02,4HSL03,4HSL04,4HSL05/                               PROF 368


      NFZ=0                                                         PROF 380
      NSURC=0                                                       PROF 382
      NTIES=0                                                       JRCMAR84
      NLIMIT =0                                                     PROF 384
      NSAL=0                                                        PROF 386


      IWAT=0                                                        PROF 400
      ISURC=0                                                       PROF 402
      ITIES=0                                                       JRCMAR84
      ILIMIT=0                                                      PROF 404
      ISOIL=0                                                       PROF 406
```

CHANGES FOR SUBROUTINE ANISO:

```
C                                                                   ANIO 154
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC, ANIO 156
     1               IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL   JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND, ANIO 160
     1               NSOIL,NTOP,PHI(20),RU(20),CU(20),NF(20)          ANIO 162
```

CHANGES FOR SUBROUTINE WATER:

```
C                                                                       WATR 122
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,   WATR 124
     1               IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL     JRCMAR84
      COMMON /BLK03/UWAT,NPZ,NPIEZ(10),XPIEZ(10,40),YPIEZ(10,40)        WATR 128
      DIMENSION ERROR(5)                                                WATR 130
```

CHANGES FOR SUBROUTINE LOADS:

```
C                                                                       LOAD 176
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,   LOAD 178
     1               IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL     JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND, LOAD 182
     1               NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)            LOAD 184
```

NEW SUBROUTINE TIES:

```
      RETURN                                                            LOAD 470
      END                                                               LOAD 472
      SUBROUTINE TIES                                                   TIES   2
C     ------------------------------------------------------------------TIES   4
C     ------------------------------------------------------------------TIES   6
C                             SUBROUTINE TIES                           TIES   8
C     ------------------------------------------------------------------TIES  10
C     ------------------------------------------------------------------TIES  12
C                                                                       TIES  14
C     FUNCTIONS -                                                       TIES  16
C                                                                       TIES  18
C        READS THE NUMBER OF TIEBACK ANCHOR LOADS.                      TIES  20
C                                                                       TIES  22
C        IF EQUAL TO ZERO, EXISTING TIEBACK LOAD DATA IS SUPRESSED OR   TIES  24
C        REACTIVATED IF PREVIOUSLY SUPRESSED.                           TIES  26
C                                                                       TIES  28
```

```
C          IF GREATER THAN ZERO, READS, CHECKS, STORES, AND PRINTS
C          TIEBACK ANCHOR LOAD DATA.
C
C    ----------------------------------------------------------------------
C
C    DEFINITIONS -
C
C          BN          ARRAY CONTAINING THE BOUNDARY NUMBERS CORRESPONDING
C                      TO THE POINT OF APPLICATION OF EACH TIEBACK LOAD
C
C          BNDS        AN ARRAY CONTAINING THE COORDINATES OF THE END
C                      POINTS DEFINING THE GROUND SURFACE AND SUBSURFACE.
C
C          COS         STANDARD FUNCTION THAT CALCULATES THE COSINE OF AN
C                      ANGLE.
C
C          DUMMY       DUMMY VARIABLE USED IN CALL OF SUBROUTINE READER
C                      WHEN AN INTEGER IS TO BE READ.
C
C          ERROR       VARIABLE REPRESENTING CURRENT ERROR CODE.
C
C          I           INDEX VARIABLE FOR ARRAY SUBSCRIPTING.
C
C          IDUMMY      DUMMY VARIABLE USED IN CALL OF SUBROUTINE READER
C                      WHEN A REAL NUMBER IS TO BE READ.
C
C          IEXIT       CONTROL CODE WHICH TERMINATES EXECUTION IF DATA IS
C                      INCONSISTENT WITH THE REQUIREMENTS OF THE PROGRAM.
C
C          INCLIN      ARRAY CONTAINING VALUES OF TIEBACK INCLINATION
C                      AS MEASURED CLOCKWISE FROM THE HORIZONTAL PLANE
C                      FOR EACH TIEBACK LOAD SPECIFIED.
C
C          INTS        CONTROL CODE WHICH SIGNALS WHETHER AN INTERSECTION
C                      HAS OCCURRED OR NOT.
C
```

```
C       INTSC3    ENTRY POINT INTO SUBROUTINE INTSCT WHICH DETERMINES  TIES 102
C                 WHETHER OR NOT A LINE SEGMENT AND A HORIZONTAL LINE  TIES 104
C                 INTERSECT AND CALCULATES THE COORDINATES OF THE      TIES 106
C                 INTERSECTION.                                        TIES 108
C                                                                      TIES 110
C       ITIES     CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM TIES 112
C                 HANDLING THE TIEBACK ANCHOR LOADS SPECIFIED BY       TIES 114
C                 SUBROUTINE TIES.                                     TIES 116
C                                                                      TIES 118
C       J         INDEX VARIABLE FOR ARRAY SUBSCRIPTING.               TIES 120
C                                                                      TIES 122
C       LENGTH    ARRAY CONTAINING VALUES OF THE LENGTH OF EACH        TIES 124
C                 TIEBACK SPECIFIED.                                   TIES 126
C                                                                      TIES 128
C       NTIE      NUMBER READ AS NUMBER OF TIEBACK ANCHOR LOADS        TIES 130
C                 SPECIFIED.                                           TIES 132
C                                                                      TIES 134
C       NTIES     NUMBER OF TIEBACK ANCHOR LOADS SPECIFIED.            TIES 136
C                                                                      TIES 138
C       PLOAD     ARRAY CONTAINING THE VALUES OF THE TIEBACK ANCHOR    TIES 140
C                 POINT LOADS APPLIED TO THE GROUND SURFACE FOR        TIES 142
C                 EACH TIEBACK ANCHOR SPECIFIED.                       TIES 144
C                                                                      TIES 146
C       QUIT      SUBROUTINE THAT DISPLAYS A TERMINATION MESSAGE,      TIES 148
C                 TERMINATES PLOTTING, AND TERMINATES EXECUTION OF     TIES 150
C                 THE PROGRAM.                                         TIES 152
C                                                                      TIES 154
C       RD        FACTOR FOR CONVERSION OF DEGREES TO RADIANS.         TIES 156
C                                                                      TIES 158
C       READER    SUBROUTINE THAT READS INTEGER OR REAL DATA IN        TIES 160
C                 FREE FORMAT.                                         TIES 162
C                                                                      TIES 164
C       SIN       STANDARD FUNCTION THAT CALCULATES THE SINE OF AN     TIES 166
C                 ANGLE.                                               TIES 168
C                                                                      TIES 170
C       SPACE     ARRAY CONTAINING THE VALUES OF THE HORIZONTAL        TIES 172
```

```
C                 SPACING BETWEEN TIEBACKS FOR EACH ROW OF TIEBACK        TIES 174
C                 ANCHORS SPECIFIED.                                      TIES 176
C                                                                         TIES 178
C       TLOAD     ARRAY CONTAINING VALUES OF EQUIVALENT HORIZONTAL LINE   TIES 180
C                 LOADS FOR EACH TIEBACK ANCHOR SPECIFIED ASSUMING A      TIES 182
C                 UNIFORM DISTRIBUTION OF LOAD TO THE GROUND SURFACE      TIES 184
C                 BETWEEN TIEBACKS.                                       TIES 186
C                                                                         TIES 188
C       TOL       TOLERANCE CONSTANT TO ACCOUNT FOR MACHINE ROUNDING.     TIES 190
C                                                                         TIES 192
C       XEND      ARRAY CONTAINING VALUES OF THE CALCULATED X             TIES 194
C                 COORDINATE OF THE END OF EACH TIEBACK SPECIFIED.        TIES 196
C                                                                         TIES 198
C       XTIE      ARRAY CONTAINING CALCULATED VALUES OF THE X             TIES 200
C                 COORDINATE OF THE POINT OF APPLICATION ON THE GROUND    TIES 202
C                 SURFACE OF EACH TIEBACK ANCHOR LOAD SPECIFIED.          TIES 204
C                                                                         TIES 206
C       YEND      ARRAY CONTAINING VALUES OF THE CALCULATED Y             TIES 208
C                 COORDINATE OF THE END OF EACH TIEBACK SPECIFIED.        TIES 210
C                                                                         TIES 212
C       YTIE      ARRAY CONTAINING INPUTTED VALUES OF THE Y COORDINATE    TIES 214
C                 OF THE POINT OF APPLICATION ON THE GROUND SURFACE OF    TIES 216
C                 EACH TIEBACK ANCHOR LOAD SPECIFIED.                     TIES 218
C                                                                         TIES 220
C-------------------------------------------------------------------------TIES 222
C-------------------------------------------------------------------------TIES 224
C                                                                         TIES 226
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,     TIES 228
     1              IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL        TIES 230
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND,   TIES 232
     1              NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)               TIES 234
      COMMON /BLK16/NTIES,INCLIN(10),PLOAD(10),SPACE(10),TLOAD(10),       TIES 236
     1              XTIE(10),YTIE(10),BN(10),LENGTH(10),XEND(10),         TIES 238
     1              YEND(10)                                              TIES 240
      DIMENSION ERROR(7)                                                  TIES 242
      DATA ERROR/4HTI01,4HTI02,4HTI03,4HTI04,4HTI05,4HTI06,4HTI07/        TIES 244
```

```
      REAL INCLIN,LENGTH                                          TIES 246
      INTEGER BN                                                  TIES 248
C                                                                 TIES 250
C   -----------------------------------                           TIES 252
C   READ NUMBER OF TIEBACK ANCHOR LOADS                           TIES 254
C   -----------------------------------                           TIES 256
C                                                                 TIES 258
      CALL READER(DUMMY,NTIE,0)                                   TIES 260
C                                                                 TIES 262
C   --------------------------------------                        TIES 264
C   CHECK FOR TIEBACK LOAD DATA SUPRESSION                        TIES 266
C   --------------------------------------                        TIES 268
C                                                                 TIES 270
      IF(NTIE.NE.0)GO TO 9                                        TIES 272
      IF(ITIES.EQ.0)GO TO 10                                      TIES 274
      ITIES=0                                                     TIES 276
      WRITE(6,108)                                                TIES 278
  108 FORMAT(///,                                                 TIES 280
     110X,'TIEBACK ANCHOR LOAD DATA HAS BEEN SUPRESSED')          TIES 282
      RETURN                                                      TIES 284
C                                                                 TIES 286
C   -----------------------------                                 TIES 288
C   CHECK IF DATA DEFINED BEFORE                                  TIES 290
C   SUPPRESSING OR REACTIVATING IT                                TIES 292
C   -----------------------------                                 TIES 294
C                                                                 TIES 296
   10 IF(NTIES.GT.0)GO TO 12                                      TIES 298
      WRITE(6,101)ERROR(1)                                        TIES 300
  101 FORMAT(/,10X,14H****  ERROR - ,A4,6H  ****,/)               TIES 302
      IEXIT=1                                                     TIES 304
C                                                                 TIES 306
C   -------------------------                                     TIES 308
C   REACTIVATE SUPPRESSED DATA                                    TIES 310
C   -------------------------                                     TIES 312
C                                                                 TIES 314
   12 ITIES=1                                                     TIES 316
```

```
      WRITE(6,109)
  109 FORMAT(///,
     110X,'SUPPRESSED TIEBACK LOAD DATA HAS BEEN REACTIVATED')
      RETURN
    9 NTIES=NTIE
C
C     ------------------------------------
C     PRINT NUMBER OF TIEBACK ANCHOR LOADS
C     ------------------------------------
C
      WRITE(6,103)NTIES
  103 FORMAT(1H1,
     1    9X,'TIEBACK LOAD(S)',//,
     1    13X,I2,' TIEBACK LOAD(S) SPECIFIED')
C
C     --------------------------------
C     CHECK TIEBACK LOAD STORAGE LIMIT
C     --------------------------------
C
      IF(NTIES.LE.10)GO TO 11
      WRITE(6,101)ERROR(2)
      CALL QUIT
C
C     ------------------------------------------
C     PRINT TIEBACK ANCHOR LOAD DATA HEADINGS
C     ------------------------------------------
C
   11 WRITE(6,102)
  102 FORMAT(//,
     1   10X,'TIEBACK',8X,'X-POS',6X,'Y-POS',5X,'LOAD',5X,'SPACING',5X,
     1   'INCLINATION',5X,'LENGTH',/,12X,'NO.',10X,'(FT)',7X,'(FT)',6X,
     1   '(LBS)',6X,'(FT)',9X,'(DEG)',9X,'(FT)',//)
C
C     ----------------------------
C     READ TIEBACK ANCHOR LOAD DATA
C     ----------------------------
```

```
C
      DO 8 I=1, NTIES
      CALL READER(DUMMY,BN(I),0)
      CALL READER(YTIE(I),IDUMMY,1)
      CALL READER(PLOAD(I),IDUMMY,1)
      CALL READER(SPACE(I),IDUMMY,1)
      CALL READER(INCLIN(I),IDUMMY,1)
      CALL READER(LENGTH(I),IDUMMY,1)
C
C    ----------------------------------
C    CHECK FOR 1ST QUADRANT LOCATION
C    ----------------------------------
C
      IF(YTIE(I).GT.-TOL)GO TO 3
  120 WRITE(6,105)ERROR(3),I
  105 FORMAT(/,10X,14H****  ERROR - ,A4,6H  ****,5X,4HTIES,I3,/)
      IEXIT=1
C
C    -----------------------------------
C    CHECK TIEBACK INCLINATION LIMITS
C    -----------------------------------
C
    3 IF(INCLIN(I).GE.0..AND.INCLIN(I).LE.90.)GO TO 16
      WRITE(6,105)ERROR(4),I
      IEXIT=1
C
C    ----------------------------------------------------
C    CALCULATE THE X COORDINATE OF THE CURRENT TIEBACK
C    ----------------------------------------------------
C
   16 INTS=0
      J=BN(I)
      CALL INTSC3(BNDS(J,1),BNDS(J,2),BNDS(J,3),BNDS(J,4),0.,0.,
     1     0.,0.,XTIE(I),YTIE(I),INTS)
      IF(INTS.EQ.1)GO TO 17
      WRITE(6,105)ERROR(5),I
```

```
      IEXIT=1
C
C     --------------------------------------------------------
C     CHECK FOR POSITIVE SPACING AND LENGTH OF TIEBACK
C     --------------------------------------------------------
C
   17 IF(SPACE(I).GE.1.)GO TO 18
      WRITE(6,105)ERROR(6),I
      IEXIT=1
   18 IF(LENGTH(I).GE.0.)GO TO 19
      WRITE(6,105)ERROR(7),I
      IEXIT=1
C
C     ------------------------------
C     PRINT TIEBACK ANCHOR LOAD DATA
C     ------------------------------
C
   19 WRITE(6,104)(I,XTIE(I),YTIE(I),PLOAD(I),SPACE(I),INCLIN(I),
     1       LENGTH(I))
  104 FORMAT(12X,I2,3X,F13.2,F11.2,F11.1,F9.1,F14.2,F13.1)
C
C     ----------------------------------------------------------------
C     CALCULATE EQUIVALENT LINE LOAD FOR EACH ROW OF TIEBACKS
C     ----------------------------------------------------------------
C
      TLOAD(I)=PLOAD(I)/SPACE(I)
      INCLIN(I)=INCLIN(I)*RD
C
C     ------------------------------------------------------------------
C     CALCULATE THE END COORDINATES OF EACH TIEBACK AND CHECK
C     FOR FIRST QUADRANT LOCATION OF END POINTS OF EACH TIEBACK
C     ------------------------------------------------------------------
C
      IF(LENGTH(I).EQ.0.)GO TO 8
      XEND(I)=XTIE(I)+LENGTH(I)*COS(INCLIN(I))
      YEND(I)=YTIE(I)-LENGTH(I)*SIN(INCLIN(I))
```

```
      IF(YEND(I).GT.-TOL)GO TO 8                                        TIES 536
      WRITE(6,105)ERROR(3),I                                            TIES 538
      IEXIT=1                                                           TIES 540
    8 CONTINUE                                                          TIES 542
      ITIES=1                                                           TIES 544
      RETURN                                                            TIES 546
      END                                                               TIES 548
      SUBROUTINE EQUAKE                                                 EQKE    2
C     ------------------------------------------------------------------EQKE    4
```

CHANGES FOR SUBROUTINE LIMITS:

```
C                                                                       LIMT 128
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,   LIMT 130
     1              IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL      JRCMAR84
      COMMON /BLK06/LIMIT(20,4),NLIMIT,NLMT                             LIMT 134
      DIMENSION ERROR(5)                                                LIMT 136
```

CHANGES FOR SUBROUTINE INTSCT:

```
C          AND CALCULATES ITS COORDINATES.                              ISCT   34
C                                                                       ISCT   36
C          ENTRY INTSC3 **********                                      JRCMAR84
C                                                                       JRCMAR84
C          CHECKS FOR INTERSECTION OF A LINE SEGMENT WITH A HORIZONTAL  JRCMAR84
C          LINE AND CALCULATES ITS COORDINATES.                         JRCMAR84
C                                                                       JRCMAR84
C     ------------------------------------------------------------------ISCT   38
C                                                                       ISCT   40
```

```
C                                                                       ISCT 122
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,   ISCT 124
     1               IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL     JRCMAR84
      INTS=0                                                            ISCT 128
C                                                                       ISCT 130


      IF((X1-X).GT.TOL.OR.(X-X2).GT.TOL)INTS=0                          ISCT 224
      RETURN                                                            ISCT 226
C                                                                       JRCMAR84
C     ************                                                      ISCT 227
      ENTRY INTSC2                                                      ISCT 228
C     ************                                                      ISCT 229
C                                                                       JRCMAR84
      INTS=0                                                            ISCT 230
      IF(ABS(X1-X2).LT.TOL)RETURN                                       ISCT 232


      IF((X1-X).LT.TOL.AND.(X-X2).LT.TOL)INTS=1                         ISCT 252
      RETURN                                                            ISCT 254
C                                                                       JRCMAR84
C     ************                                                      JRCMAR84
      ENTRY INTSC3                                                      JRCMAR84
C     ************                                                      JRCMAR84
C                                                                       JRCMAR84
      INTS=0                                                            JRCMAR84
      IF(ABS(X1-X2).LT.TOL)RETURN                                       JRCMAR84
C                                                                       JRCMAR84
C   -----------------------------------                                 JRCMAR84
C   CHECK FOR AN INTERSECTION BETWEEN A                                 JRCMAR84
C   LINE SEGMENT AND A HORIZONTAL LINE                                  JRCMAR84
C   -----------------------------------                                 JRCMAR84
C                                                                       JRCMAR84
```

```
      B12=(Y1-Y2)/(X1-X2)                                              JRCMAR84
      A12=Y1-B12*X1                                                    JRCMAR84
      X=(Y-A12)/B12                                                    JRCMAR84
      IF((Y1-Y).LT.TOL.AND.(Y-Y2).LT.TOL)INTS=1                        JRCMAR84
      RETURN                                                           JRCMAR84
      END                                                              ISCT 256
      SUBROUTINE SURFAC                                                SURF   2
```

CHANGES FOR SUBROUTINE SURFAC:

```
C                                                                      SURF 142
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,  SURF 144
     1               IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL    JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND, SURF 148
     1               NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)           SURF 150


     2          (Y2-Y1)))                                              MGOODMAN
      YCNTR = (X2-X3)/(Y3-Y2)*(XCNTR - XHALF2) + YHALF2                MGOODMAN
      RADIUS = SQRT((XCNTR - X2)**2 + (YCNTR - Y2)**2)                 MGOODMAN
      WRITE(6,107)XCNTR,YCNTR,RADIUS                                   JRCMAR84
  107 FORMAT(/,10X,'CIRCLE CENTER AT X = ',F6.1,' ; Y = ',F6.1,        JRCMAR84
     1    '  AND RADIUS, ',F6.1)                                       JRCMAR84
  104 RETURN                                                           MGOODMAN
      END                                                              SURF 416
      SUBROUTINE RANDOM                                                RAND   2
```

CHANGES FOR SUBROUTINE RANDOM:

```
C         CALLS SUBROUTINES PLTN, ENTRY PLT4, AND PLOTIN TO PLOT PROFILE RAND   34
C         AND, IF SPECIFIED, THE PIEZOMETRIC SURFACES, SEARCHING LIMITS, RAND   36
C         BOUNDARY LOADS, AND TIEBACK LOADS.                             JRCMAR84
C                                                                        RAND   40
C         SELECTS INITIATION POINTS AND DIRECTIONAL LIMITATIONS FOR TRIALRAND   42

                                                                         RAND   66
C         CALLS SUBROUTINE PLOTIN TO REPEAT PLOT OF PROFILE AND, IF      RAND   68
C         SPECIFIED, PIEZOMETRIC SURFACES, SEARCHING LIMITS,             JRCMAR84
C         BOUNDARY LOADS, AND TIEBACK LOADS.                             JRCMAR84
C                                                                        RAND   72
C         CALLS SUBROUTINES ENTRY PLT3 AND ENTRY PLOTN3 TO PLOT THE      RAND   74
C

                                                                         RAND  614
C
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,    RAND  616
     1             IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL        JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND,  RAND  620
     1             NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)               RAND  622
```

CHANGES FOR SUBROUTINE RANSUF:

```
                                                                         RANS  626
C
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,    RANS  628
     1             IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL        JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND,  RANS  632
     1             NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)               RANS  634
```

CHANGES FOR SUBROUTINE BLKSUF:

```
C                                                                    BLKS 238
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,   BLKS 240
     1            IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL        JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND, BLKS 244
     1            NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)               BLKS 246
```

CHANGES FOR SUBROUTINE BLOCK2:

```
C                                                                    BK2- 276
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,   BK2- 278
     1            IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL        JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND, BK2- 282
     1            NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)               BK2- 284
```

CHANGES FOR SUBROUTINE EXECUT:

```
C                 AFFECTED BY THE SEARCHING SUBROUTINES RANDOM AND      EXEC  52
C                 BLOCK.                                                EXEC  54
C                                                                       JRCMAR84
C      ITIES      CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM  JRCMAR84
C                 HANDLING THE TIEBACK ANCHOR LOADS SPECIFIED BY        JRCMAR84
C                 SUBROUTINE TIES.                                      JRCMAR84
C                                                                       EXEC  56
C      PLOTIN     SUBROUTINE WHICH PLOTS WITH A PLOTTING DEVICE THE     EXEC  58


C                                                                       EXEC  84
C      SLICES     SUBROUTINE WHICH DIVIDES SLIDING MASS INTO SLICES.    EXEC  98
C                                                                       JRCMAR84
C      TRANS      SUBROUTINE WHICH TRANSFERS THE EQUIVALENT LINE LOAD   JRCMAR84
```

```
C                    FOR EACH TIEBACK TO THE BASE OF EACH SLICE USING      JRCMAR84
C                    FLAMANTS'S FORMULAS.                                  JRCMAR84
C                                                                          EXEC 100
C       WEIGHT       SUBROUTINE WHICH CALCULATES THE TOTAL WEIGHT OF EACH  EXEC 102

                                                                           EXEC 112
C     COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,      EXEC 114
     1               IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL        JRCMAR84
C                                                                          EXEC 118
C   ------------------------------------------------------------          EXEC 120

      CALL SLICES                                                          EXEC 130
      CALL WEIGHT                                                          EXEC 132
      IF(ITIES.EQ.1)CALL TRANS                                             JRCMAR84
      CALL FACTR                                                           EXEC 134
      IF(ISEARC.EQ.1)RETURN                                                EXEC 136
```

CHANGES FOR SUBROUTINE SLICES:

```
C                                                                          SLIC 208
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,      SLIC 210
     1               IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL        JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND,    SLIC 214
     1               NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)               SLIC 216
```

CHANGES FOR SUBROUTINE WEIGHT:

```
C                                                                    WGHT 398
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,  WGHT 400
     1              IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL      JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND, WGHT 404
     1              NSOIL,NTOP,PHI(20),RU(20),CU(20),NF(20)             WGHT 406
```

NEW SUBROUTINE TRANS:

```
      RETURN                                                          SLWT 160
      END                                                             SLWT 162
      SUBROUTINE TRANS                                                TRAN   2
C    -----------------------------------------------------------------TRAN   4
C    -----------------------------------------------------------------TRAN   6
C                          SUBROUTINE TRANS                           TRAN   8
C    -----------------------------------------------------------------TRAN  10
C    -----------------------------------------------------------------TRAN  12
C                                                                     TRAN  14
C    FUNCTIONS -                                                      TRAN  16
C                                                                     TRAN  18
C        TRANSFERS THE EQUIVALENT LINE LOAD FOR EACH TIEBACK TO THE   TRAN  20
C        BASE OF EACH SLICE USING FLAMANT'S FORMULAS.                 TRAN  22
C                                                                     TRAN  24
C    -----------------------------------------------------------------TRAN  26
C                                                                     TRAN  28
C    DEFINITIONS -                                                    TRAN  30
C                                                                     TRAN  32
C        ALPHA     ARRAY CONTAINING VALUES OF THE ANGLES OF THE BASE  TRAN  34
C                  OF EACH SLICE.                                     TRAN  36
C                                                                     TRAN  38
C        ALPHA1    ARRAY CONTAINING ANGLES USED TO CALCULATE THE NORMAL TRAN  40
C                  AND TANGENTIAL COMPONENTS OF THE TIEBACK FORCES AT TRAN  42
C                  THE BASE OF EACH SLICE.                            TRAN  44
```

```
C                                                                      TRAN  46
C       ATAN      STANDARD FUNCTION THAT CALCULATES THE ARCTANGENT OF  TRAN  48
C                 AN ANGLE.                                            TRAN  50
C                                                                      TRAN  52
C       BN        ARRAY CONTAINING THE BOUNDARY NUMBERS CORRESPONDING  TRAN  54
C                 TO THE POINT OF APPLICATION OF EACH TIEBACK LOAD     TRAN  56
C                                                                      TRAN  58
C       BNDS      ARRAY CONTIANING THE COORDINATES OF THE END POINTS   TRAN  60
C                 DEFINING THE GROUND SURFACE AND SUBSURFACE           TRAN  62
C                 BOUNDARIES.                                          TRAN  64
C                                                                      TRAN  66
C       CORR      ARRAY CONTAINING CORRECTION FACTORS TO MAKE THE SUM  TRAN  68
C                 OF THE TIEBACK FORCES ON TRIAL FAILURE SURFACE EQUAL TRAN  70
C                 TO THE APPLIED LOAD FOR EACH TIEBACK SPECIFIED.      TRAN  72
C                                                                      TRAN  74
C       COS       STANDARD FUNCTION THAT CALCULATES THE COSINE OF      TRAN  76
C                 AN ANGLE.                                            TRAN  78
C                                                                      TRAN  80
C       DEV       ARRAY CONTAINING VALUES OF ANGLES BETWEEN THE        TRAN  82
C                 HORIZONTAL PLANE AND THE LINE BETWEEN THE POINT      TRAN  84
C                 OF APPLICATION OF A TIEBACK AND THE CENTER OF THE    TRAN  86
C                 BASE OF A SLICE FOR EACH SLICE.                      TRAN  88
C                                                                      TRAN  90
C       DIST      ARRAY CONTAINING VALUES OF THE DISTANCE BETWEEN THE  TRAN  92
C                 POINT OF APPLICATION OF A TIEBACK AND THE CENTER OF  TRAN  94
C                 THE BASE OF A SLICE.                                 TRAN  96
C                                                                      TRAN  98
C       DX        ARRAY CONTAINING VALUES OF THE WIDTH OF EACH SLICE.  TRAN 100
C                                                                      TRAN 102
C       FLAG      FLAG USED TO CONTROL CALCULATION OF THE Y COORDINATE TRAN 104
C                 OF THE BASE OF EACH SLICE.                           TRAN 106
C                                                                      TRAN 108
C       I         INDEX VARIABLE USED FOR ARRAY SUBSCRIPTING.          TRAN 110
C                                                                      TRAN 112
C       INCLIN    ARRAY CONTAINING VALUES OF TIEBACK INCLINATION       TRAN 114
C                 AS MEASURED CLOCKWISE FROM THE HORIZONTAL PLANE      TRAN 116
```

```
C                 FOR EACH TIEBACK LOAD SPECIFIED.                    TRAN 118
C                                                                     TRAN 120
C       INTS      CONTROL CODE WHICH SIGNALS WHETHER AN INTERSECTION  TRAN 122
C                 HAS OCCURRED OR NOT.                                TRAN 124
C                                                                     TRAN 126
C       INTSCT    SUBROUTINE WHICH DETERMINES WHETHER OR NOT TWO LINE TRAN 128
C                 SEGMENTS INTERSECT AND CALCULATES THE COORDINATES   TRAN 130
C                 OF THE INTERSECTION.                                TRAN 132
C                                                                     TRAN 134
C       INTSC2    ENTRY POINT INTO SUBROUTINE INTSCT WHICH DETERMINES TRAN 136
C                 WHETHER OR NOT A LINE SEGMENT AND A VERTICAL LINE   TRAN 138
C                 INTERSECT AND CALCULATES THE COORDINATES OF THE     TRAN 140
C                 INTERSECTION.                                       TRAN 142
C                                                                     TRAN 144
C       J         VARIABLE USED FOR ARRAY SUBSCRIPTING.               TRAN 146
C                                                                     TRAN 148
C       K         VARIABLE USED FOR ARRAY SUBSCRIPTING.               TRAN 150
C                                                                     TRAN 152
C       LENGTH    ARRAY CONTAINING VALUES OF THE LENGTH OF EACH       TRAN 154
C                 TIEBACK SPECIFIED.                                  TRAN 156
C                                                                     TRAN 158
C       NSLICE    NUMBER OF SLICES THAT SLIDING MASS IS DIVIDED INTO. TRAN 160
C                                                                     TRAN 162
C       NSURF     NUMBER OF POINTS DEFINING A TRIAL FAILURE SURFACE.  TRAN 164
C                                                                     TRAN 166
C       NTIES     NUMBER OF TIEBACK ANCHOR LOADS SPECIFIED.           TRAN 168
C                                                                     TRAN 170
C       NTOP      NUMBER OF GROUND SURFACE BOUNDARIES.                TRAN 172
C                                                                     TRAN 174
C       PERPEN    90 DEGREES IN RADIANS.                              TRAN 176
C                                                                     TRAN 178
C       PI        PI.                                                 TRAN 180
C                                                                     TRAN 182
C       PRAD      ARRAY CONTAINING VALUES OF THE UNRESOLVED TIEBACK   TRAN 184
C                 FORCE ON THE BASE OF EACH SLICE.                    TRAN 186
C                                                                     TRAN 188
C       PSUM      ARRAY CONTAINING VALUES OF THE SUM OF THE TIEBACK   TRAN 190
```

```
C                FORCES ON THE BASE OF EACH SLICE OVER THE WHOLE     TRAN 192
C                TRIAL FAILURE SURFACE FOR THE CURRENT TIEBACK LOAD. TRAN 194
C                                                                    TRAN 196
C     RD         FACTOR OF CONVERSION FROM DEGREES TO RADIANS.       TRAN 198
C                                                                    TRAN 200
C     SIN        STANDARD FUNCTION THAT CALCULATES THE SINE OF AN    TRAN 202
C                ANGLE.                                              TRAN 204
C                                                                    TRAN 206
C     SQRT       STANDARD FUNCTION THAT CALCULATES THE SQUARE ROOT   TRAN 208
C                OF A NUMBER.                                        TRAN 210
C                                                                    TRAN 212
C     SURF       ARRAY CONTAINING THE X AND Y COORDINATES OF POINTS  TRAN 214
C                DEFINING THE TRIAL FAILURE SURFACE.                 TRAN 216
C                                                                    TRAN 218
C     TLOAD      ARRAY CONTAINING VALUES OF EQUIVALENT HORIZONTAL LINETRAN 220
C                LOADS FOR EACH TIEBACK ANCHOR SPECIFIED ASSUMING A  TRAN 222
C                UNIFORM DISTRIBUTION OF LOAD TO THE GROUND SURFACE  TRAN 224
C                BETWEEN TIEBACKS.                                   TRAN 226
C                                                                    TRAN 228
C     TNORM      ARRAY CONTAINING VALUES OF THE TOTAL TIEBACK LOAD   TRAN 230
C                ACTING NORMAL TO THE BASE OF EACH SLICE FOR ALL     TRAN 232
C                TIEBACK LOADS SPECIFIED.                            TRAN 234
C                                                                    TRAN 236
C     TTAN       ARRAY CONTAINING VALUES OF THE TOTAL TIEBACK LOAD   TRAN 238
C                ACTING TANGENT TO THE BASE OF EACH SLICE FOR ALL    TRAN 240
C                TIEBACK LOADS SPECIFIED.                            TRAN 242
C                                                                    TRAN 244
C     TTHETA     ARRAY CONTAINING VALUES OF ANGLES BETWEEN THE LINE  TRAN 246
C                OF ACTION OF A TIEBACK AND THE LINE BETWEEN THE     TRAN 248
C                POINT OF APPLICATION OF A TIEBACK AND THE CENTER OF TRAN 250
C                THE BASE OF A SLICE FOR EACH SLICE.                 TRAN 252
C                                                                    TRAN 256
C     X          ARRAY CONTAINING THE X COORDINATES OF THE CENTER OF TRAN 258
C                THE BASE OF EACH SLICE.                             TRAN 260
C                                                                    TRAN 262
C     XEND       ARRAY CONTAINING VALUES OF THE CALCULATED X         TRAN 264
C                COORDINATE OF THE END OF EACH TIEBACK SPECIFIED.    TRAN 266
```

```
C                                                                      TRAN 268
C     XINT      X COORDINATE OF INTERSECTION OF TWO LINE SEGMENTS.    TRAN 270
C                                                                      TRAN 272
C     XTIE      ARRAY CONTAINING VALUES OF THE X COORDINATE OF THE    TRAN 274
C               POINT OF APPLICATION ON THE GROUND SURFACE OF EACH    TRAN 276
C               TIEBACK ANCHOR LOAD SPECIFIED.                        TRAN 278
C                                                                      TRAN 280
C     YB        ARRAY CONTAINING VALUES OF THE Y COORDINATE OF THE    TRAN 282
C               BASE OF EACH SLICE.                                   TRAN 284
C                                                                      TRAN 286
C     YEND      ARRAY CONTAINING VALUES OF THE CALCULATED Y           TRAN 288
C               COORDINATE OF THE END OF EACH TIEBACK SPECIFIED.      TRAN 290
C                                                                      TRAN 292
C     YINT      Y COORDINATE OF INTERSECTION OF TWO LINE SEGMENTS.    TRAN 294
C                                                                      TRAN 296
C     YTIE      ARRAY CONTAINING VALUES OF THE Y COORDINATE OF THE    TRAN 298
C               POINT OF APPLICATION ON THE GROUND SURFACE OF EACH    TRAN 300
C               TIEBACK ANCHOR LOAD SPECIFIED.                        TRAN 302
C                                                                      TRAN 304
C----------------------------------------------------------------------TRAN 306
C----------------------------------------------------------------------TRAN 308
C                                                                      TRAN 310
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,  TRAN 312
     1             IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL      TRAN 314
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND, TRAN 316
     1             NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)             TRAN 318
      COMMON /BLK05/NSURF,SURF(100,2)                                  TRAN 320
      COMMON /BLK08/NSLICE,X(300)                                      TRAN 322
      COMMON /BLK09/ALPHA(200),BETA(200),DX(200),SLTP(200),UALPHA(200), TRAN 324
     1             UBETA(200),WTT(200)                                 TRAN 326
      COMMON /BLK16/NTIES,INCLIN(10),PLOAD(10),SPACE(10),TLOAD(10),    TRAN 328
     1             XTIE(10),YTIE(10),BN(10),LENGTH(10),XEND(10),       TRAN 330
     1             YEND(10)                                            TRAN 332
      COMMON /BLK17/ALPHA1(200),CORR(10),DEV(200),DIST(200),           TRAN 334
     1             PNORM(200),PRAD(200),PSUM(200),PTAN(200),           TRAN 336
     1             TTHETA(200),YB(200)                                 TRAN 338
      COMMON /BLK18/TNORM(200),TTAN(200)                               TRAN 340
```

```
      REAL INCLIN,LENGTH
      INTEGER BN
      FLAG=0.
      PI=3.1415927
      PERPEN=90.*RD
      DO 1 J=1,NSLICE
      TNORM(J)=0.
      TTAN(J)=0.
    1 CONTINUE
      DO 2 I=1,NTIES
C
C     ----------------------------------------------------------
C     CHECK TO SEE IF END OF TIEBACK EXTENDS
C     BEYOND TRIAL FAILURE SURFACE
C     ----------------------------------------------------------
C
      IF(LENGTH(I).EQ.0.)GO TO 7
      DO 3 L=2,NSURF
      CALL INTSCT(XTIE(I),YTIE(I),XEND(I),YEND(I),SURF(L-1,1),
     1     SURF(L-1,2),SURF(L,1),SURF(L,2),XINT,YINT,INTS)
      IF(INTS.EQ.1)GO TO 7
    3 CONTINUE
      GO TO 2
    7 PSUM(I)=0.
      DO 4 J=1,NSLICE
C
C     ----------------------------------------------------------
C     CALCULATE Y COORDINATE OF BASE OF SLICE
C     ----------------------------------------------------------
C
      IF(FLAG.EQ.1.)GO TO 10
      DO 5 L=2,NSURF
      CALL INTSC2(SURF(L-1,1),SURF(L-1,2),SURF(L,1),SURF(L,2),
     1      0.,0.,0.,0.,X(J),YB(J),INTS)
      IF(INTS.EQ.1)GO TO 10
    5 CONTINUE
C
```

```
C     ------------------------------------------------------------------
C     CHECK FOR GROUND SURFACE INTERSECTION WITH THE LINE BETWEEN THE
C     POINT OF APPLICATION OF THE TIEBACK LOAD AND THE CENTER OF THE
C     BASE OF THE SLICE
C     ------------------------------------------------------------------
C
   10 DO 6 K=1,NTOP
      IF(K.EQ.BN(I))GO TO 6
      IF(XTIE(I).GE.X(J))GO TO 12
      CALL INTSCT(XTIE(I),YTIE(I),X(J),YB(J),BNDS(K,1),BNDS(K,2),
     1      BNDS(K,3),BNDS(K,4),XINT,YINT,INTS)
      GO TO 11
   12 CALL INTSCT(X(J),YB(J),XTIE(I),YTIE(I),BNDS(K,1),BNDS(K,2),
     1      BNDS(K,3),BNDS(K,4),XINT,YINT,INTS)
   11 IF(INTS.EQ.1)GO TO 4
    6 CONTINUE
C
C     -----------------------------------------------------------
C     CALCULATE THE ANGLE BETWEEN THE LINE OF ACTION OF THE
C     TIEBACK AND THE LINE BETWEEN THE POINT OF APPLICATION
C     OF THE TIEBACK AND THE CENTER OF THE BASE OF THE SLICE
C     -----------------------------------------------------------
C
      IF((X(J)-XTIE(I)).GT.0.)GO TO 15
      DEV(J)=PI-ATAN((YTIE(I)-YB(J))/(XTIE(I)-X(J)))
      GO TO 16
   15 DEV(J)=ATAN((YTIE(I)-YB(J))/(X(J)-XTIE(I)))
   16 TTHETA(J)=DEV(J)-INCLIN(I)
C
C     -----------------------------------------------------------
C     CALCULATE THE DISTANCE BETWEEN THE POINT OF APPLICATION
C     OF THE TIEBACK AND THE CENTER OF THE BASE OF THE SLICE
C     -----------------------------------------------------------
C
      DIST(J)=SQRT((YTIE(I)-YB(J))**2+(X(J)-XTIE(I))**2)
C
C     -------------------------------------------
```

```
C   CALCULATE TIEBACK LOAD ON BASE OF SLICE
C   ---------------------------------------------------
C
      PRAD(J)=2*TLOAD(I)*DX(J)*COS(TTHETA(J))/(DIST(J)*PI*COS(ALPHA(J)))
      PSUM(I)=PSUM(I)+PRAD(J)*COS(TTHETA(J))
    4 CONTINUE
      FLAG=1.
C
C   -------------------------------------------------------------
C   CALCULATE TIEBACK BASE FORCE CORRECTION FACTOR
C   -------------------------------------------------------------
C
      CORR(I)=TLOAD(I)/PSUM(I)
C
C   -------------------------------------------------------------
C   CALCLUATE THE NORMAL AND TANGENTIAL COMPONENTS
C   OF THE TIEBACK LOAD AT THE BASE OF EACH SLICE
C   -------------------------------------------------------------
C
      DO 8 J=1,NSLICE
      PRAD(J)=PRAD(J)*CORR(I)
      ALPHA1(J)=PERPEN-ALPHA(J)-DEV(J)
      PNORM(J)=PRAD(J)*COS(ALPHA1(J))
      PTAN(J)=PRAD(J)*SIN(ALPHA1(J))
C
C   ---------------------------------------------------------------
C   SUM TIEBACK LOADS ON EACH SLICE FOR ALL TIEBACKS
C   ---------------------------------------------------------------
C
      TNORM(J)=TNORM(J)+PNORM(J)
      TTAN(J)=TTAN(J)+PTAN(J)
    8 CONTINUE
    2 CONTINUE
      RETURN
      END
      SUBROUTINE FACTR
C    ----------------------------------------------------------------------------------------------
```

CHANGES FOR SUBROUTINE FACTR:

```
C                                                                   FCTR  76
C     A4        TERM USED IN FACTOR OF SAFETY CALCULATION           MGOODMAN
C                                                                   MGOODMAN
C     A5        TERM USED IN FACTOR OF SAFETY CALCULATION           MGOODMAN
C                                                                   JRCMAR84
C     A6        TERM USED IN FACTOR OF SAFETY CALCULATION           JRCMAR84
C                                                                   MGOODMAN
C     BETA      ARRAY CONTAINING VALUES OF THE ANGLE OF THE TOP OF  FCTR  78
C               EACH SLICE.                                         FCTR  80


C     TAN       STANDARD FUNCTION THAT CALCULATES THE SINE OF AN    FCTR 300
C               ANGLE.                                              FCTR 302
C                                                                   JRCMAR84
C     TNORM     ARRAY CONTAINING VALUES OF THE TOTAL TIEBACK LOAD   JRCMAR84
C               ACTING NORMAL TO THE BASE OF EACH SLICE FOR ALL     JRCMAR84
C               TIEBACK LOADS SPECIFIED.                            JRCMAR84
C                                                                   FCTR 304
C     TP        TANGENT OF ANGLE PHI.                               FCTR 306
C                                                                   JRCMAR84
C     TTAN      ARRAY CONTAINING VALUES OF THE TOTAL TIEBACK LOAD   JRCMAR84
C               ACTING TANGENT TO THE BASE OF EACH SLICE FOR ALL    JRCMAR84
C               TIEBACK LOADS SPECIFIED.                            JRCMAR84
C                                                                   FCTR 308
C     UALPHA    ARRAY CONTAINING VALUES OF THE HYDROSTATIC FORCE    FCTR 310


C                                                                   FCTR 334
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,   FCTR 336
     1             IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL       JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND, FCTR 340
     1             NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)              FCTR 342
```

```
     1            PERPEN,SURFS(100,2,12),TSURF,YBPT,YEPT,YMIN        FCTR 362
      COMMON /BLK15/ M,MB                                            FCTR 363
      COMMON /BLK18/TNORM(200),TTAN(200)                             JRCMAR84
      COMMON /BLK20/RADIUS                                           MGOODMAN
      COMMON /BLK21/HIGHT(200),HGHTEQ(200)                           MGOODMAN
      DIMENSION A1(200),A2(200),A3(200)                              FCTR 364
      EQUIVALENCE (ALPHA(1),A1(1)), (BETA(1),A2(1)), (DX(1),A3(1))   FCTR 366


C     ---------------------------------------------------------------FCTR 456
C                                                                    FCTR 458
      IF (MB.EQ.1) GO TO 40                                          MGOODMAN
C                                                                    MGOODMAN
C     SIMPLIFIED JANBU A-TERMS                                       MGOODMAN
C                                                                    MGOODMAN
      A0 = CSLICE*DX(I) + TF*(WTT(I)*(1.0-VKCOEF) + (TNORM(I)-UALPHA(I))JRCMAR84
     1      *CA + UBETA(I)*CB + P(I)*CD)                             JRCMAR84
      A1(I) = A0/CA**2                                               FCTR 462
      A2(I)=WTT(I)*(TA+KCOEF-VKCOEF*TA)+UBETA(I)*(CB*TA-SB)+P(I)*(CD*TA-FCTR 464
     1   SD) - TTAN(I)/CA                                            JRCMAR84
      A3(I)=TA*TF                                                    FCTR 468
      SUMB = SUMB + A2(I)                                            FCTR 469
      GO TO 2                                                        MGOODMAN
C                                                                    MGOODMAN
C     SIMPLIFIED BISHOP A-TERMS                                      MGOODMAN
C                                                                    MGOODMAN
40    A1(I) = CSLICE*DX(I)/CA + TF/CA*(WTT(I)*(1.0-VKCOEF) - TTAN(I)*SA JRCMAR84
     1          + P(I)*CD + UBETA(I)*CB + (TNORM(I) - UALPHA(I))*CA)  JRCMAR84
      A2(I) = TF*TA                                                  MGOODMAN
      A3(I) = (WTT(I)*(1.0-VKCOEF) + UBETA(I)*CB + P(I)*CD)*SA       MGOODMAN
      A4 = (UBETA(I)*SB + P(I)*SD)*(CA-HIGHT(I)/RADIUS)              MGOODMAN
      A5 = KCOEF*WTT(I)*(CA-HGHTEQ(I)/RADIUS)                        MGOODMAN
      A6 = TTAN(I)                                                   JRCMAR84
      SUMB = SUMB + A3(I) - A4 + A5 - A6                             JRCMAR84
    2 CONTINUE                                                       FCTR 470
C                                                                    FCTR 472
```

CHANGES FOR SUBROUTINE SCALER:

```
C                    HANDLING THE SURCHARGE LOADS SPECIFIED BY SUBROUTINE SCAL  56
C                    LOADS.                                               SCAL  58
C                                                                         JRCMAR84
C        ITIES       CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM JRCMAR84
C                    HANDLING THE TIEBACK ANCHOR LOADS SPECIFIED BY       JRCMAR84
C                    SUBROUTINE TIES.                                     JRCMAR84
C                                                                         SCAL  60
C        IWAT        CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM SCAL  62


C        NSURC       NUMBER OF BOUNDARY LOADS SPECIFIED.                  SCAL  98
C                                                                         JRCMAR84
C        NTIES       NUMBER OF TIEBACK ANCHOR LOADS SPECIFIED.            JRCMAR84
C                                                                         SCAL 100
C        NTOP        NUMBER OF GROUND SURFACE BOUNDARIES.                 SCAL 102


C        SURC        ARRAY CONTAINING X COORDINATES OF THE END POINTS     SCAL 114
C                    DEFINING THE EXTENT OF LOADING.                      SCAL 116
C                                                                         JRCMAR84
C        XEND        ARRAY CONTAINING VALUES OF THE CALCULATED X          JRCMAR84
C                    COORDINATE OF THE END OF EACH TIEBACK SPECIFIED.     JRCMAR84
C                                                                         SCAL 118
C        XPIEZ       ARRAY CONTAINING X COORDINATES OF POINTS DEFINING    SCAL 120


C                                                                         SCAL 144
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,     SCAL 146
     1            IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL          JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND,   SCAL 150
     1            NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)                 SCAL 152
```

```
     1            PERPEN,SURFS(100,2,12),TSURF,YBPT,YEPT,YMIN        SCAL 164
      COMMON /BLK14/SCLE                                             SCAL 166
      COMMON /BLK16/NTIES,INCLIN(10),PLOAD(10),SPACE(10),TLOAD(10),  JRCMAR84
     1            XTIE(10),YTIE(10),BN(10),LENGTH(10),XEND(10),      JRCMAR84
     1            YEND(10)                                           JRCMAR84
      REAL MAXX,MAXY,LIMIT                                           SCAL 168
C                                                                    SCAL 170
```

```
      IF(LIMIT(I,3).GT.MAXX)MAXX=LIMIT(I,3)                          SCAL 208
    6 CONTINUE                                                       SCAL 210
    5 IF(ITIES.EQ.0)GO TO 12                                         JRCMAR84
      DO 11 I=1,NTIES                                                JRCMAR84
      IF(XEND(I).GT.MAXX)MAXX=XEND(I)                                JRCMAR84
   11 CONTINUE                                                       JRCMAR84
   12 IF(ISURC.EQ.0)GO TO 7                                          JRCMAR84
      IF(SURC(NSURC,2).GT.MAXX)MAXX=SURC(NSURC,2)                    SCAL 214
      DO 9 I=1,NSURC                                                 SCAL 216
```

CHANGES FOR SUBROUTINE PLOTIN:

```
C                 AFFECTED BY SEARCHING LIMITS ESTABLISHED BY        PLOT  76
C                 SUBROUTINE LIMITS.                                 PLOT  78
C                                                                    JRCMAR84
C       INCLIN    ARRAY CONTAINING VALUES OF TIEBACK INCLINATION     JRCMAR84
C                 AS MEASURED CLOCKWISE FROM THE HORIZONTAL PLANE    JRCMAR84
C                 FOR EACH TIEBACK SPECIFIED.                        JRCMAR84
C                                                                    PLOT  80
C       IPLOT     CONTROL CODE WHICH CONTROLS TRANSLATION OF AXES FOR PLOT  82
```

```
C                HANDLING THE SURCHARGE LOADS SPECIFIED BY SUBROUTINE PLOT   98
C                LOADS.                                               PLOT  100
C                                                                     JRCMAR84
C     TTIES      CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM JRCMAR84
C                HANDLING THE TIEBACK ANCHOR LOADS SPECIFIED BY       JRCMAR84
C                SUBROUTINE TIES.                                     JRCMAR84
C                                                                     PLOT  102
C     IWAT       CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM PLOT  104

C                                                                     PLOT  128
C     MAXL       MAXIMUM INTENSITY OF THE BOUNDARY LOADS SPECIFIED.   PLOT  130
C                                                                     JRCMAR84
C     MAXTL      MAXIMUM INTENSITY OF THE EQUIVALENT LINE LOADS       JRCMAR84
C                FOR ALL TIEBACKS SPECIFIED.                          JRCMAR84
C                                                                     PLOT  132
C     N          VARIABLE USED TO TEMPORARILY STORE THE NUMBER OF     PLOT  134

C                DEFINING EACH OF THE TEN MOST CRITICAL TRIAL         PLOT  166
C                SURFACES.                                            PLOT  168
C                                                                     JRCMAR84
C     NTIES      NUMBER OF TIEBACK ANCHOR LOADS SPECIFIED.            JRCMAR84
C                                                                     PLOT  170
C     NTOP       NUMBER OF GROUND SURFACE BOUNDARIES.                 PLOT  172

C                EACH OF THE TEN MOST CRITICAL TRIAL SURFACES.        PLOT  214
C                                                                     PLOT  216
C     SYMBOL     EXTERNAL SUBROUTINE THAT ACTIVATES THE PLOTTING PEN  NOV76EBO
C                TO PLOT CHARACTERS OR ON-CENTER SYMBOLS.             NOV76EBO
C                                                                     JRCMAR84
C     TL         A SCALED EQUIVALENT LINE LOAD FOR A GIVEN TIEBACK.   JRCMAR84
```

```
C                                                                       JRCMAR84
C     TLOAD     ARRAY CONTAINING VALUES OF EQUIVALENT HORIZONTAL LINEJRCMAR84
C               LOADS FOR EACH TIEBACK ANCHOR SPECIFIED ASSUMING A   JRCMAR84
C               UNIFORM DISTRIBUTION OF LOAD TO THE GROUND SURFACE   JRCMAR84
C               BETWEEN TIEBACKS.                                    JRCMAR84
C                                                                    NOV76EB0
C     W         SCALED WIDTH OF A BOX FOR FOR SLIDING BLOCK SEARCH.  PLOT 218
C                                                                    PLOT 220

C                                                                    PLOT 226
C     X         X COORDINATE OF GEOMETRY POINT TO BE PLOTTED.        PLOT 228
C                                                                    JRCMAR84
C     XEND      ARRAY CONTAINING VALUES OF THE CALCULATED X          JRCMAR84
C               COORDINATE OF THE END OF EACH TIEBACK SPECIFIED.     JRCMAR84
C                                                                    PLOT 230
C     XL        ARRAY CONTAINING VALUES OF THE X COORDINATE OF THE   PLOT 232

C     XR        ARRAY CONTAINING VALUES OF THE X COORDINATE OF THE   PLOT 244
C               RIGHT END OF EACH BOX CENTERLINE.                    PLOT 246
C                                                                    JRCMAR84
C     XTIE      ARRAY CONTAINING CALCULATED VALUES OF THE X          JRCMAR84
C               COORDINATE OF THE POINT OF APPLICATION ON THE GROUND JRCMAR84
C               SURFACE OF EACH TIEBACK ANCHOR LOAD SPECIFIED.       JRCMAR84
C                                                                    PLOT 248
C     X1        SCALED X COORDINATE OF A CORNER OF A BOX FOR SLIDING PLOT 250
C               BLOCK SEARCH.                                        PLOT 252
C                                                                    PLOT 254
C     Y         Y COORDINATE OF GEOMETRY POINT TO BE PLOTTED.        PLOT 256
C                                                                    JRCMAR84
C     YEND      ARRAY CONTAINING VALUES OF THE CALCULATED Y          JRCMAR84
C               COORDINATE OF THE END OF EACH TIEBACK SPECIFIED.     JRCMAR84
C                                                                    PLOT 258
C     YL        ARRAY CONTAINING VALUES OF THE Y COORDINATE OF THE   PLOT 260
```

```
C     YSURC      ARRAY CONTAINING THE CALCULATED Y COORDINATES OF THE PLOT 278
C                ENDS OF THE BOUNDARY LOADS ON THE GROUND SURFACE.    PLOT 280
C                                                                     JRCMAR84
C     YTIE       ARRAY CONTAINING INPUTTED VALUES OF THE Y COORDINATE JRCMAR84
C                OF THE POINT OF APPLICATION ON THE GROUND SURFACE OF JRCMAR84
C                EACH TIEBACK ANCHOR LOAD SPECIFIED.                  JRCMAR84
C                                                                     PLOT 282
C     Y1         SCALED Y COORDINATE OF A CORNER OF A BOX FOR SLIDING PLOT 284

                                                                      PLOT 294
C                                                                     PLOT 296
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC, JRCMAR84
     1           IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL       PLOT 300
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND, PLOT 302
     1           NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)

                                                                      PLOT 316
      COMMON /BLK13/NGRID,WIDTH(10),XL(10),XR(10),YL(10),YR(10)       PLOT 318
      COMMON /BLK14/SCLE                                              JRCMAR84
      COMMON /BLK16/NTIES,INCLIN(10),PLOAD(10),SPACE(10),TLOAD(10),   JRCMAR84
     1           XTIE(10),YTIE(10),BN(10),LENGTH(10),XEND(10),        JRCMAR84
     1           YEND(10)                                             PLOT 320
      EQUIVALENCE (DX,X1),(DY,Y1)                                     JRCMAR84
      REAL LIMIT,LOAD,MAXL,MAXTL,INCLIN,LENGTH                        PLOT 324
C                                                                     PLOT 326
C   --------------------

                                                                      PLOT 467
      CALL PLOT(X,Y,3)                                                PLOT 468
   26 CONTINUE                                                        JRCMAR84
   25 IF(ISURC.EQ.0)GO TO 31                                          PLOT 472
C                                                                     PLOT 474
C   ---------------------------------------------------
```

```
      CALL SYMBOL(X,Y,0.07,1HP,0.,.1)                                   PLOT 523
    8 CONTINUE                                                          PLOT 524
C                                                                       JRCMAR84
C     ---------------------------------------                           JRCMAR84
C     PLOT TIEBACK LOADS, IF APPLICABLE                                 JRCMAR84
C     ---------------------------------------                           JRCMAR84
C                                                                       JRCMAR84
   31 IF(ITIES.EQ.0)GO TO 3                                             JRCMAR84
      MAXTL=TLOAD(1)                                                    JRCMAR84
      IF(NTIES.EQ.1)GO TO 32                                            JRCMAR84
      DO 33 I=2,NTIES                                                   JRCMAR84
      IF(TLOAD(I).GT.MAXTL)MAXTL=TLOAD(I)                               JRCMAR84
   33 CONTINUE                                                          JRCMAR84
   32 DO 34 I=1,NTIES                                                   JRCMAR84
      X=XTIE(I)/SCLE                                                    JRCMAR84
      Y=YTIE(I)/SCLE                                                    JRCMAR84
      CALL SYMBOL(X,Y,0.07,1HT,0.,.1)                                   JRCMAR84
      CALL PLOT(X,Y,3)                                                  JRCMAR84
      TL=.3*TLOAD(I)/MAXTL                                              JRCMAR84
      DX=TL*COS(INCLIN(I))                                              JRCMAR84
      DY=TL*SIN(INCLIN(I))                                              JRCMAR84
      X=X-DX                                                            JRCMAR84
      Y=Y+DY                                                            JRCMAR84
      CALL PLOT(X,Y,2)                                                  JRCMAR84
      CALL SYMBOL(X,Y,0.07,1HT,0.,.1)                                   JRCMAR84
      CALL PLOT(X,Y,3)                                                  JRCMAR84
      IF(LENGTH(I).EQ.0.)GO TO 34                                       JRCMAR84
      X=XEND(I)/SCLE                                                    JRCMAR84
      Y=YEND(I)/SCLE                                                    JRCMAR84
      CALL PLOT(X,Y,2)                                                  JRCMAR84
      CALL SYMBOL(X,Y,0.07,1HT,0.,.1)                                   JRCMAR84
   34 CONTINUE                                                          PLOT 526
C                                                                       PLOT 528
C     ------------------------------------------------------------
```

CHANGES FOR SUBROUTINE PLTN:

```
C                       HANDLING THE SURCHARGE LOADS SPECIFIED BY SUBROUTINE PLTN   82
C                       LOADS.                                               PLTN   84
C                                                                            JRCMAR84
C          ITIES        CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM JRCMAR84
C                       HANDLING THE TIEBACK ANCHOR LOADS SPECIFIED BY       JRCMAR84
C                       SUBROUTINE TIES.                                     JRCMAR84
C                                                                            PLTN   86
C          IWAT         CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM PLTN   88
C                       DEFINING EACH OF THE TEN MOST CRITICAL TRIAL         PLTN  164
C                       SURFACES.                                            PLTN  166
C                                                                            JRCMAR84
C          NTIES        NUMBER OF TIEBACK ANCHOR LOADS SPECIFIED.            JRCMAR84
C                                                                            PLTN  168
C          PLT          ARRAY CONTAINING THE CHARACTER PLOT MATRIX.          PLTN  170


C                                                                            PLTN  210
C          TOL          TOLERANCE CONSTANT TO ACCOUNT FOR MACHINE ROUNDING.  PLTN  212
C                                                                            JRCMAR84
C          XEND         ARRAY CONTAINING VALUES OF THE CALCULATED X          JRCMAR84
C                       COORDINATE OF THE END OF EACH TIEBACK SPECIFIED.     JRCMAR84
C                                                                            PLTN  214
C          XPIEZ        ARRAY CONTAINING X-COORDINATES OF POINTS DEFINING    PLTN  216
C                       WATER SURFACE.                                       PLTN  218
C                                                                            JRCMAR84
C          XTIE         ARRAY CONTAINING CALCULATED VALUES OF THE X          JRCMAR84
C                       COORDINATE OF THE POINT OF APPLICATION ON THE GROUND JRCMAR84
C                       SURFACE OF EACH TIEBACK ANCHOR LOAD SPECIFIED.       JRCMAR84
C                                                                            PLTN  220
C          YPIEZ        ARRAY CONTAINING Y-COORDINATES OF POINTS DEFINING    PLTN  222
C                       WATER SURFACE.                                       PLTN  224
C                                                                            JRCMAR84
C          YEND         ARRAY CONTAINING VALUES OF THE CALCULATED Y          JRCMAR84
```

```
C                 COORDINATE OF THE END OF EACH TIEBACK SPECIFIED.     JRCMAR84
C                                                                      PLTN 226
C        YSURC    ARRAY CONTAINING THE CALCULATED Y COORDINATES OF THE PLTN 228
C                 ENDS OF THE BOUNDARY LOADS ON THE GROUND SURFACE.    PLTN 230
C                                                                      JRCMAR84
C        YTIE     ARRAY CONTAINING INPUTTED VALUES OF THE Y COORDINATE JRCMAR84
C                 OF THE POINT OF APPLICATION ON THE GROUND SURFACE OF JRCMAR84
C                 EACH TIEBACK ANCHOR LOAD SPECIFIED.                  JRCMAR84
C                                                                      PLTN 232
C    ------------------------------------------------------------------PLTN 234
C    ------------------------------------------------------------------PLTN 236

C                                                                      PLTN 238
      COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,   PLTN 240
     1              IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL     JRCMAR84
      COMMON /BLK02/BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND, PLTN 244
     1              NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)            PLTN 246


     1              PERPEN,SURFS(100,2,12),TSURF,YBPT,YEPT,YMIN        PLTN 258
      COMMON /BLK14/SCLE                                               PLTN 260
      COMMON /BLK16/NTIES,INCLIN(10),PLOAD(10),SPACE(10),TLOAD(10),    JRCMAR84
     1              XTIE(10),YTIE(10),BN(10),LENGTH(10),XEND(10),      JRCMAR84
     1              YEND(10)                                           JRCMAR84
      DIMENSION PLT(49,51),SYMB(20),AXIS(9),SCL(9)                     JRCMAR84
      REAL LIMIT                                                       PLTN 264
      DATA SYMB/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H0,1H ,1H+,1H-,1H*,PLTN 266
     1    1HW,1HL,1HS,1H.,1H/,1HT/                                     JRCMAR84
      DATA AXIS/1HX,1H ,1HA,1HX,1HI,1HS,1H ,1HF,1HT/                   PLTN 270
C                                                                      PLTN 272
```

```
      IYY=IY                                                          PLTN 586
   23 CONTINUE                                                        PLTN 588
C                                                                     JRCMAR84
C    ------------------------------------------------------------     JRCMAR84
C    POSITION POINTS DEFINING TIEBACK LOADS, IF APPLICABLE            JRCMAR84
C    ------------------------------------------------------------     JRCMAR84
C                                                                     JRCMAR84
   30 IF(ITIES.EQ.0)GO TO 10                                          JRCMAR84
      DO 32 I=1,NTIES                                                 JRCMAR84
      CALL POSTN(XTIE(I),YTIE(I),IX,IY)                               JRCMAR84
      PLT(IX-1,IY)=SYMB(I)                                            JRCMAR84
      PLT(IX,IY)=SYMB(20)                                             JRCMAR84
      IF(LENGTH(I).EQ.0.)GO TO 32                                     JRCMAR84
      CALL POSTN(XEND(I),YEND(I),IX,IY)                               JRCMAR84
      PLT(IX,IY)=SYMB(20)                                             JRCMAR84
      PLT(IX+1,IY)=SYMB(I)                                            JRCMAR84
   32 CONTINUE                                                        JRCMAR84
C                                                                     PLTN 590
C    -----------------------------------------------------            PLTN 592
```

LINES TO INTERCHANGE IN STABL4
TO RUN PROGRAM ON AN IBM COMPUTER

PROGRAM STABL4

```
      DIMENSION KEYW(16),ERROR(5),WAR(100)                       JRCMAR84
      REAL*8 MKEYW,KEYW                                          STBL 251  (ADD)
      TOL=.001                                                   STBL 258
      CALL PLOTS(WAR,400)                                        STBL 292
```

SUBROUTINE PROFIL

```
      DIMENSION TITLE(10),DESCR(10), ERROR(11)                   PROF 344
  113 FORMAT(20A4)                                               PROF 440
  112 FORMAT(//,10X,'PROBLEM DESCRIPTION   ',10A4,/32X,10A4,//)  PROF 443
```

SUBROUTINE INTSCT

```
      ENTRY INTSC2(X1,Y1,X2,Y2,X3,Y3,X4,Y4,X,Y,INTS)             ISCT 228
      ENTRY INTSC3(X1,Y1,X2,Y2,X3,Y3,X4,Y4,X,Y,INTS)             JRCMAR84
```

SUBROUTINE RANDOM

```
      CALL NUMBER (1.5,6.0,0.1,FLOAT(TAL),0.,-1)                 RAND1859
      CALL NUMBER (3.8,5.7,0.1,FSS(1),0.,3)                      RAND1868
```

SUBROUTINE PLOTIN

```
      CALL AXIS(0.,0.,6HX-AXIS,-6,8.,0.,0.,SCLE,1.,1,1,0,.125)         PLOT 364
      CALL AXIS(0.,0.,6HY-AXIS,6,5.,1.5708,0.,SCLE,1.,1,1,0,.125)      PLOT 366
      CALL NUMBER(4.95,5.7,0.1,FS,0.,3)                                 PLOT 567
```

LINES TO ADD TO STABL4 TO RUN
PROGRAM ON AN IBM COMPUTER

FUNCTION RANF (ADD AFTER SUBROUTINE PSTN)

```
      FUNCTION RANF(X)                                                  RANF    2
      INTEGER XN,SEED                                                   RANF    4
      DATA XN,SEED/131072,27487/                                        *3-1-83*
      SEED=MOD(SEED*78125,XN)                                           RANF    8
      IF(SEED .LT. 0) SEED=SEED+XN                                      *3-1-83*
      RANF=FLOAT(SEED)/FLOAT(XN)                                        RANF   12
      RETURN                                                            RANF   14
      END                                                               RANF   16
```

NOTE: Some of the above changes reflect adjustments to use the Calcomp plotter on local system (ISHC-IBM360). They may have to be adjusted accordingly for other systems.

COVER DESIGN BY ALDO GIORGINI